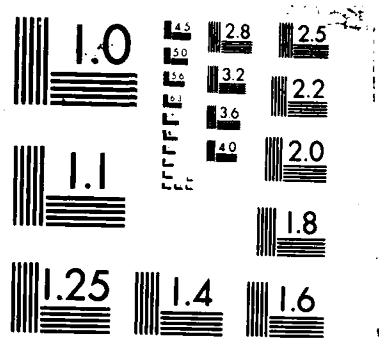
AD-A177 383 GLOBAL LOW ORBIT MESSAGE RELAY (GLOMR) SATELLITE APPLICATIONS DEVELOPMENT PRGRAM(U) ARDAK CORP MCLEAN VA J L SLACK ET AL. 30 SEP 86 ARDAK-8603-01 1/2

UNCLASSIFIED N00014-86-C-0330 F/G 17/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

(13)

Report Number ARDAK-8603-01

Global Low Orbit Message Relay Satellite (GLOMR) Applications Development Program

Final Technical Report

Contract Number: N00014-86-C-0330

30 September 1986

Prepared by:
ARDAK Corporation
1493 Chain Bridge Road
McLean, VA 22101

Sponsored by:
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 Wilson Boulevard
Arlington, VA 22209

Contracting Agency:
OFFICE OF NAVAL RESEARCH
800 N. Quincy Street
Arlington, VA 22217-5000

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS: NONE
2a. SECURITY CLASSIFICATION AUTHORITY: N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT: UNLIMITED
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): ARDAK-8603-01	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: ARDAK CORPORATION; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: OFFICE OF NAVAL RESEARCH
6c. ADDRESS (City, State and ZIP Code): 1493 CHAIN BRIDGE ROAD, SUITE 302 McLEAN, VIRGINIA 22101	7b. ADDRESS (City, State and ZIP Code): 800 NORTH QUINCY STREET ARLINGTON, VIRGINIA 22217-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: DARPA; 8b. OFFICE SYMBOL (If applicable): STO	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N00014-86-C-0330
8c. ADDRESS (City, State and ZIP Code): 1400 WILSON BLVD ARLINGTON, VIRGINIA 22209	10. SOURCE OF FUNDING NOS.: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.

11. TITLE (Include Security Classification) Global Low Orbit Message Relay (GLOMR) Applications Development Program (U)

12. PERSONAL AUTHOR(S) JOHN L. SLACK, NEIL R. HELM

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final Technical Rpt	FROM 860326 TO 860930	860930	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Satellite Communications

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Global Low Orbit Message Relay (GLOMR) satellite is a proof-of-concept effort sponsored by the Defense Advanced Research Projects Agency (DARPA). The spacecraft was taken into orbit by the Space Shuttle, Challenger, in late October 1985 and successfully ejected into a circular orbit of 324km. The primary goals of this Applications Development program were: (1) to develop a full understanding of GLOMR's capabilities; (2) to demonstrate their potential for application to a variety of U.S. Government missions; and, (3) to develop a potential user base for future low cost message relay and geopositioning satellites. A successful series of tests and demonstrations with interested user/customers was conducted, with the results meeting the goals and objectives of the program. The final success is shown by the knowledge that the user community is presently planning and budgeting for follow-on spacecraft and systems.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code); 22c. OFFICE SYMBOL

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

SECURITY CLASSIFICATION OF THIS PAGE

Table of Contents

Section		Page
1	Executive Summary	1
2	Introduction	6
3	Background	7
4	Task Descriptions	10
	4.1 Project Planning	10
	4.2 Write Basic Geolocate Routines	10
	4.3 Contract with DSI	11
	4.4 Contract with PRC	11
	4.5 Document Current DSI Work	12
	4.6 Operate MGS	12
	4.7 Write GLOMR PET Interface Specification	13
	4.8 Integrate Mission Planning	14
	4.9 Demonstrate PET Message	14
	4.10 Write Message Mailbox Handler	14
	4.11 Generate Mission Planning Demonstration Displays	15
	4.12 Install PET Geolocate Calculator	15
	4.13 Integrate/Test Beacons	15
	4.14 Write Planning Macros	16
	4.15 Analyze DSI Data for Geolocation	16
	4.16 Test Geolocate Capability and Analyze	17
	4.17 Integrate Operations Segments	19
	4.18 Demonstrate GLOMR System	19
	4.19 Write Final Report/Briefing	20
5	Conclusions	21
6	Recommendations	22
7	Bibliography	25

Attachments

1. GLOMR Applications Development Work Plan
2. GLOMR Test Plan for the First DARPA Demonstration
3. U.S. Customs Service, San Diego, California, Global Low Orbit Message Relay (GLOMR) Satellite Briefing
4. GLOMR Test Plan for the U.S. Army Demonstration
5. GLOMR Test Plan for the U.S. Customs Service Demonstration, San Diego, California
6. GLOMR Anomaly Report

List of Figures

Figure 3-1	GLOMR Technical Characteristics
Figure 3-2	GLOMR Orbital Characteristics
Figure 3-3	GLOMR Operational Characteristics
Figure 4-1	GLOMR Activity Timeline
Figure 4-2	Master Ground Station Message Output
Figure 4-3	Master Ground Station Block Diagram
Figure 4-4	List of Message Relay and Geolocation Demonstrations
Figure 4-5	Typical GLOMR Messages
Figure 4-6	GEODE Pass Plot
Figure 4-7	Geolocation Concept
Figure 4-8	Master Ground Station Geolocation Output

GLOMR FINAL REPORT

N00014-86-C-0330

1. EXECUTIVE SUMMARY

The Global Low Orbiting Message Relay (GLOMR) satellite is a proof-of-concept effort sponsored by the Defense Advanced Research Projects Office (DARPA). Being aware of costs and complexity of defense satellite programs, DARPA wanted to experiment with a simple, low cost spacecraft that could be built rapidly with off-the-shelf avionics components. The spacecraft was also to be designed to fit into NASA's new Space Shuttle Get-Away-Special (GAS) launch capability, which promised inexpensive entry into low earth orbits. This spacecraft was built by Defense Systems Inc. of McLean, Virginia in 1984. The satellite was to have the capability to store and forward packetized data messages using low cost ground user communications equipment, and also have the capability to geolocate radio frequency emitters.

The GLOMR spacecraft was initially taken into orbit by the Space Shuttle, Challenger, in late April 1985, but the opening mechanism for the "GAS" canister malfunctioned and the satellite was returned to Earth with the Space Shuttle. The spacecraft was launched again in late October 1985 and this time successfully ejected into a circular orbit of 324 kilometers (175 nautical miles). The spacecraft in that orbit was initially estimated to have an orbital lifetime of 250-300 days (later revised to 400-500 days). Early telemetry showed that the spacecraft support systems were operating successfully, however, the communications subsystem experienced problems from the initial test period. Corrections to the ground station equipment improved the communications somewhat, and by year end 1985 the satellite was operating consistently enough that further demonstrations of its overall capabilities were warranted.

ARDAK Corporation, in the role of integrating contractor, submitted a proposal on January 10, 1986, with subcontractors Defense Systems Inc. (DSI) and Planning Research Corporation (PRC), to provide an applications development program. The primary goals of the program were to integrate and develop a full understanding of GLOMR's capabilities and to demonstrate their potential for application to a variety of U.S. Government missions. A secondary goal was to develop a potential user base for future low cost message relay and geopositioning satellites. The four main tasks of the proposal included: (1) to document current operations; (2) to develop software for mission planning and geolocation; (3) to operate the Master Ground Station (MGS) and the satellite system; and, (4) to test and demonstrate the Portable Earth Terminal (PET) and overall system capabilities to potential satellite users.

A contract was awarded to ARDAK. The first task (documenting current operations) revealed that the message relay communications had an estimated throughput of only 6% during the first 1,000 orbits. Therefore, some of the proposed subtasks, such as arranging a message mailbox program, were deemed to be of lesser priority, and efforts were concentrated on how best to improve and maximize the current system.

Mission planning analyses were initiated on how the satellite's abilities could best be directed. Special software was designed to assist in demonstrating those abilities. Testing of specific hardware and software systems and functions were undertaken to comprehend the potential of the complete GLOMR end-to-end system.

The first demonstration of the message relay capability was accomplished for DARPA at their Rosslyn, Virginia headquarters. An esoteric message was uplinked from the MGS to the satellite and downlinked to the Portable Earth Terminal on DARPA's roof. The message was received satisfactorily and the demonstration was considered a success.

DARPA had requested that message relay tests be conducted from outside the Washington, D.C. "pass window". Plans were then initiated for tests from a DSI facility near Santa Barbara, California. While these tests did not meet all of the planned objectives, they were successful in demonstrating several objectives such as, cross country relay of messages, accurate prediction of remote pass windows, and identification of environmental and operational constraints of the Portable Earth Terminal.

To better test and demonstrate the geolocation capability of the GLOMR satellite, two beacon transmitters were designed and procured by ARDAK. These small, battery powered units were fully transportable and could be attached to a moving vehicle or taken to sea in a ship where they could simulate an unmanned buoy. The beacons, as part of their successful acceptance tests, were able to transmit a seven second coded message which was received and "clocked" by the satellite. This coded data contained the time the satellite received the code and the frequency of the transmitter. The data were then transmitted down to the Master Ground Station as raw geolocation data on a subsequent pass. These data are then normally fed into a specially designed software program that computes the frequency, time of receipt, location of the satellite in an inverse doppler method into a longitude, latitude and altitude location.

The beacons were then integrated into a planned series of geolocation tests. These tests were plagued by a number of technical, operational and procedural problems which resulted in a lack of any consistent data to be used to determine the beacon's location.

A planned series of demonstrations to interested user/customers was scheduled and, although shortened somewhat by the lack of any geolocation usable data, was deemed to be successful. In addition to the first demonstration at DARPA, message relay demonstrations were conducted at DSI Headquarters in McLean, Virginia and also at Fort Bragg, North Carolina with successful messages being able to be transmitted and received. Geolocation demonstrations were conducted at the Washington Monument in Washington, D. C.,

El Paso, Texas and San Diego, California. In the latter demonstrations, the user equipment (beacon) was operated with the satellite, the concept was explained and excellent feedback was received from discussions with field personnel.

The user/customer community proved to be one of the most successful aspects of the GLOMR Applications Development contract. The U.S. Navy continues to search for improved modes of communications over the trackless ocean areas of the world. The GLOMR system has the ability, for example, to collect information from unmanned bouys along with tracking their movement. The Navy is seriously investigating GLOMR follow-on activities. The Army has special forces and rapid deployment troops that are prepared to trade off some of the heavier, more traditional communications systems for ones that can be activated rapidly and are easy to use. This type of mission requirement may have a synergy with tactical rockets that could be used to launch GLOMR type satellites into appropriate orbit elevations and inclinations. The Army is investigating this synergy which would allow a "storage and launch as needed" satellite communications capability to meet specific missions or fill gaps in larger systems. The Customs Service has an increasing need to track the movements of boats and other vehicles for the purpose of interdicting the transportation of illegal drugs. Therefore continuing efforts are planned by the Customs Service to design and procure low cost beacons/tags that can be attached to and aid in the tracking and location of vehicles. In addition, the Department of Justice and the Atomic Energy Commission have the requirements of tracking the movement of vehicles, which is why they are continuing their interest in GLOMR.

A series of recommendations resulted from the evaluation of this development effort. One recommendation states that low cost satellite systems are required by a user/customer community that is experiencing budget realities. However, this community is accustomed to higher communications throughput, for example, and more user friendly operations. Therefore, future GLOMR type spacecraft and systems need to adhere to low cost goals

and objectives, but some additional attention needs to be provided in the areas of design, fabrication and testing to improve operational efficiency and user satisfaction. Additional recommendations call for more study of mission requirements, a tradeoff study on space segment versus ground user equipment, and the need for additional investigations into frequency allocations.

On balance, ARDAK's GLOMR Development Applications contract must be considered a success. The spacecraft development began as a low cost proof-of-concept effort with the GLOMR satellite satisfying that goal by operating successfully in orbit, and continuing to operate into an extended orbital lifetime. Real progress and meaningful results were achieved, although limitations, especially in the communications and geolocation areas, frustrated some tests and demonstrations. The ultimate success in an applications development contract is the knowledge that the user community is presently planning and budgeting for follow-on spacecraft and systems.

2. INTRODUCTION

This ARDAK final report first reviews the background of low orbiting satellites and the origins, goals and objectives of the GLOMR program. This report then reviews the tasks set forth in the Statement of Work (on a task by task basis) and describes how those tasks were completed and the results achieved. Specific attachments to this Final Report will contain test plans and other deliverables that are required by the contract. In addition, attachments to this report will point out many of the anomalies uncovered while working on this GLOMR contract and change recommendations will be made on how the anomalies may be corrected for later developments and generations of spacecraft.

3. BACKGROUND

The Global Low Orbiting Message Relay (GLOMR) satellite proof-of-concept effort was sponsored by the Defense Advanced Research Projects Agency (DARPA) to restudy the application of low orbit, low cost satellites for Department of Defense missions. Beginning with the Relay experimental satellite in the early 1960s, the assets and liabilities of a circular orbit were well understood. While some satellites and missions, such as reconnaissance, continued to use lower orbits, the bulk of the communications satellites went to a geosynchronous (35,000 km) orbit. There the trend went to larger, more sophisticated communications satellites which became very expensive and tended to aggregate missions and needs into one central system. While these satellites and systems were generally reliable, a number of launch failures along with some system malfunctions, budget constraints and the lack of many small users to get into the large aggregate, caused a restudy of lower cost, low orbiting satellites.

GLOMR was funded in 1984 and designed and built by Defense Systems Incorporated (DSI) of McLean, Virginia. The primary objective of DSI was to build a spacecraft using off-the-shelf avionics components in less than a year, for less than a million dollars. This objective was met.

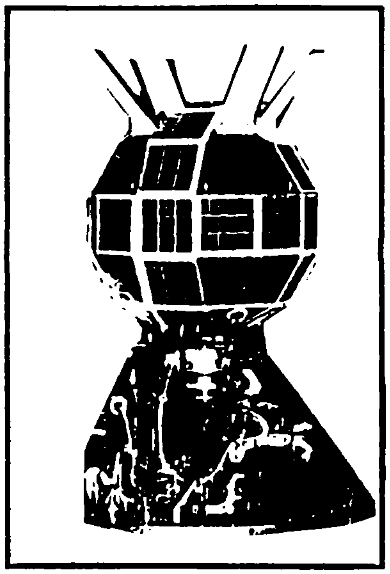
The spacecraft was assembled, then tested by NASA at the Goddard Space Flight Center in February 1985. The testing included some normal pre-flight tests as well as the special safety testing required for launch by the space shuttle. While some damage was done to the spacecraft during pressure testing just weeks prior to its planned launch, the spacecraft was mated with the launch mechanism in the Get-Away-Special (GAS) canister and put aboard the Space Shuttle Challenger. The shuttle was launched in late April 1985, but the canister mechanism and lid failed to operate properly, and the GLOMR spacecraft was returned to Earth with the shuttle. It is noteworthy that the resulting tests showed that

the spacecraft's pressurized hull had failed and the internal components had "out gased", but that no degradation or damage was seen when compared to pre-test results.

It was not immediately known when the GLOMR satellite might be assigned again to a Space Shuttle for launch, as the Get-Away-Special priorities are not very high. This unknown provided time for further analysis, and recommendations were made to make changes in the spacecraft. One example is the addition of a ranging module that would assist in the geolocation. Other recommendations were made to leave the spacecraft basically as is and work hard to get a launch again as soon as possible. This later point of view prevailed and DARPA, DSI and ARDAK worked through the middle of 1985, and were successful in getting GLOMR assigned to the Space Shuttle Challenger on Mission 61-A, which had the European Space Agency (ESA) Spacelab as its primary cargo. This Challenger mission was launched on October 30, 1985 and a few hours later the GLOMR spacecraft was successfully ejected from its canister. Figure 3-1 is a photograph of the spacecraft with its launch characteristics.

The GLOMR satellite reached an apogee of 324 kilometers (175 nautical miles) with an inclination of 57°. This circular orbit had a period of approximately 90 minutes. This type of orbit normally allows the spacecraft to be seen from the ground (visibility window) for a series of three passes each 90 minutes apart. The spacecraft is then not visible for at least six hours, with the potential of three passes beginning again. The visibility time is a factor of the slant range from the "viewing" point on the ground to the spacecraft in a particular orbit. Given blockage from hills, trees, buildings, etc., the satellite would have to rise at least 5° above the horizon to insure visibility. While a communications exchange or message could take place in a few seconds, a visibility window of a few minutes was chosen to insure adequate visibility time. The maximum visibility window extended to 12 minutes (horizon-to-horizon) when the orbit brought the satellite directly over the viewing point. Figure 3-2 shows the Orbital Characteristics.

GLOMR TECHNICAL CHARACTERISTICS



- o Weight - 68.5 kg
- o Diameter - 49 cm (Antenna Tips)
- o Height - 52 cm
- o Construction - 0.64 cm Brass
- o Stabilization - None (slow tumble)
- o Altitude Adjustment - None

Figure 3-1. GLOMR Technical Characteristics

GLOMR ORBITAL CHARACTERISTICS

Launch:	Shuttle Mission 61A
GLOMR Launch Date:	31 Oct 85
Launch Method:	GAS Can Spring Ejection
Seperation Velocity:	1.2 m/Second
Inclination:	56.98 Degrees
Launch Altitude:	324 km
Period:	90 Minutes
Single Pass Visibility:	2 - 10 Minutes
	3-4 Consecutive Revolutions
	6 Hour Gap
Re-Entry:	Early 1987

Figure 3-2. GLOMR Orbital Characteristics

The spacecraft exterior is made of brass in the form of a 62 sided polyhedron, weighs 64 kg and has a maximum diameter of 48 cm at the antenna tips. The square facets of the satellite are covered with solar cells that deliver 12 watts of prime power. Figure 3-3 shows the spacecraft characteristics.

The satellite design was made simple both for cost and ease of operation and, therefore, only one frequency was used both for transmit and receive. The frequency, 187.4MHz, is allocated to the U.S. Navy. The output power of the satellite is 10 watts radiating from four omnidirectional "paddle" antennas.

GLOMR OPERATIONAL CHARACTERISTICS

- o Prime Power - 12 Watts
- o EIRP - 10 Watts
- o Operating Frequency - 287.4 MHz Xmit & Rcv
- o Transmission Scheme - BPSK, 1200 Baud
- o Modem - Burst

Figure 3-3. GLOMR Operational Characteristics

4. TASK DESCRIPTIONS

This section provides a task by task description of the efforts set out in the ARDAK Statement of Work and how these tasks were accomplished during the contract. The task numbers provide a cross reference to the Work Plan (attachment 1). The ordering of the tasks is chronological as shown in the activity timeline (Figure 4-1).

4.1 Task 1.1 - Project planning. The project planning task, produced the revised Work Plan during the first reporting period. The Work Plan was based on the statement of work and the proposal. It described how each task was to be performed. A copy of the Work Plan is provided as attachment 1.

Technical direction and status reporting were also included in this task. Four progress reports (0001AA, 0001AB, 0001AC, and 0001AD) were written and delivered to the appropriate contractual agencies on schedule. This final report (0001AE) completes the reporting obligations of the contract.

4.2 Task 4.1 - Write basic geolocate routines. Basic geolocation routines were written and tested as proposed The geolocation software was to be based upon "off-the-shelf" DSI software which DSI had obtained from its subsidiary, Polar Research Labs (PRL) of Carpinteria, California. The PRL software had been used operationally with the TIROS satellite and was written in Basic on an IBM PC. This PRL software was analyzed and the decision was made to use it only as an example. New FORTRAN code was written by PRC on a Digital Equipment Corporation Micro PDP-11/73 running under the RSX-11M+ operating system. Approximately 400-500 lines of new code have been integrated with the PRC mission planning software, called GEODE, and uses GEODE's element set data base and ephemeris generation. The geolocation software, which completes this task, can be executed at PRC, or remotely via dial up telephone and modem.

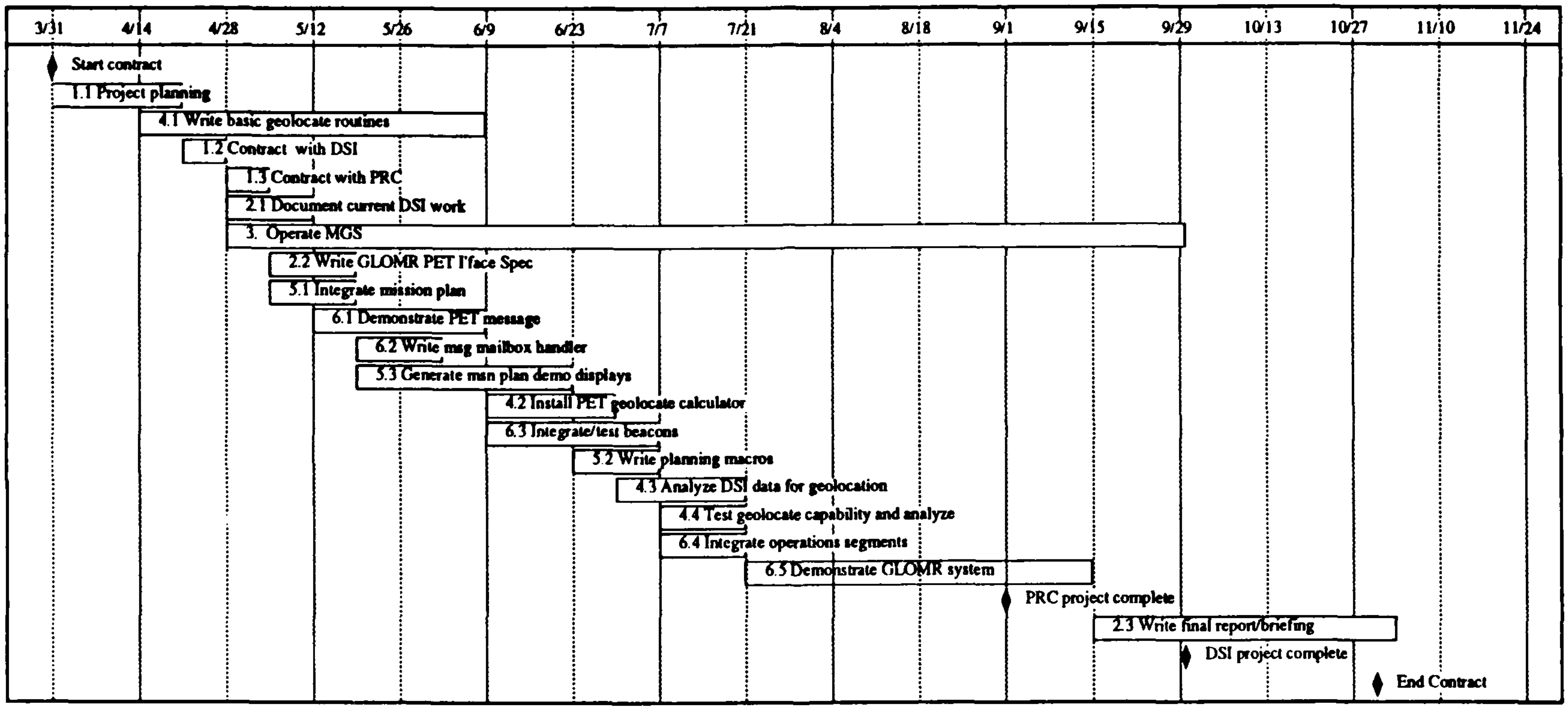


Figure 4-1. GLOMR Activity Timeline

The input format is that of the GLOMR geolocation messages which encode numbers by individual bytes.

4.3 Task 1.2 - Contract with DSI. DSI was responsible for the design and fabrication of the GLOMR spacecraft, the Master Ground Station, and the Portable Earth Terminal. Therefore it was efficient to subcontract to DSI and have them continue many of the hardware and operational tasks, while ARDAK took the lead in the systems integration areas. The subcontracting process was uneventful, and the following tasks were accomplished with DSI taking primary responsibility or sharing the duties with ARDAK and PRC:

- 2.1 Document current DSI work (shared with ARDAK)
- 2.2 Write GLOMR PET interface specification (shared with ARDAK)
- 3. Operate MGS
- 4.2 Install PET geolocate calculator (shared with ARDAK)
- 5.1 Integrate mission planning (shared with PRC)
- 6.2 Write message mailbox handler (shared with ARDAK)
- 6.4 Integrate operations segments (shared with PRC)

4.4 Task 1.3 - Contract with PRC. Planning Research Corporation (PRC) has extensive experience in software preparation for highly technical programs like the GLOMR Applications Development effort. While the prime contract administration took longer than expected, which delayed the finalizing of the subcontracts, there were no subcontractual problems and PRC had full or shared responsibility for the following software tasks:

- 5.1 Integrate mission planning (shared with DSI)
- 5.2 Write planning macros

- 5.3 Generate mission planning demonstration displays
- 6.4 Integrate operations segments (shared with DSI)

4.5 Task 2.1 - Document current DSI work. The process of establishing formats, test procedures, and for standardizing the documentation has been completed. The DSI log books were reviewed for accuracy and the proper listing of operational data and anomalies. Recommendations were made to DSI to prepare a specific form for the reporting of anomalies. The anomaly reports were then used as inputs to the list of action areas that were needed to correct the problem areas and make suggested system refinements. Attachment 6 provides an example of a DSI anomaly report. It contains satellite contact statistics, anomalies and limitations in the satellite system and refinements and actions taken to correct the limitations.

4.6 Task 3 - Operate MGS. The operation of the Master Ground Station (MGS) was a continuing task assigned to DSI, that extended to the end of the operational part of the Applications Development Program. The MGS support has been satisfactory, but it should be noted that DSI had other GLOMR customer contracts and studies so that this contract effort had to compete with others for satellite and MGS time. The DSI support included station keeping and demonstration support. Station keeping functions included scheduling operations, resetting the GLOMR clock, message preparation, orbital pass determination, telemetry readout and analysis, and post pass closeout and record-keeping. Similarily, demonstration support included orbital pass determination, operations scheduling, message preparation and uplink, message downlink and readout, briefings, exhibiting equipment, and record-keeping. Figure 4-2 is an example of MGS message outputs.

The MGS originally consisted of a Digital Equipment Corporation LSI 11/73 microcomputer running RT-11/TSX+, a communications microprocessor, a transmitter and receiver, and an antenna. The transmitter, receiver and communications processor are essentially the same components as are installed inside the GLOMR satellite. This cost

MESSAGE

```
        Record #116

Type ID         1
ODAC            1
DDAC            1
Msg ID          1
Msg Count      58
Msg Source    SAT
Msg Number       0
Time Gathered 11/02/85   19:22:23
glomr test msg intended for delivery 11-03-85 00:24:00 gmt
        ***************
```

Figure 4-2. Master Ground Station Message Output

saving arrangement is an integral part of the GLOMR concept. Figure 4-3 is a block diagram display of the MGS. As shown, the original microcomputer has been replaced with an IBM PC XT. The MGS is located at the DSI office building on Westpark Drive in McLean, Virginia. The PC is installed in an office with support equipment such as a communications receiver. The communications processor, transmitter, and receiver are mounted in a suitcase sized aluminum case located at the base of the antenna on the roof of the building. The antenna is an omnidirectional dipole quadrafiler approximately 138cm tall with a 101cm circular aluminum ground plane. Each of the four "paddle type" dipoles measures 19cm in length. The transmit/receive equipment in the case suffered water damage and possible lightning damage during a storm in August 1986. In addition, moisture and corrosion to the transmit/receive switch has caused several outages.

4.7 Task 2.2 - Write GLOMR PET Interface Specification. The GLOMR to Portable Earth Terminal (PET, also called Portable Access Terminal, PAT) interface specification was completed by ARDAK, and used to procure the beacons. These specifications were provided to AVCOM Incorporated of Richmond, Virginia who met or exceeded all specifications within cost and schedule. It should be noted that the ARDAK/AVCOM team was successful in delivering the beacons on schedule, with major changes to the specifications being made just two weeks before the delivery date. These changes in the length and sophistication of the specific transmission sequence, caused modifications to all three sections (radio transmitter, computer, and battery power) of the beacons. The beacons transmit a seven second coded message which is used to demonstrate the geolocation capabilities of the GLOMR satellite system. The beacons are small (7cm x 23cm x 23cm), hand held, battery operated transmitters, with 2 watts of output power being signaled to the satellite. The received signal frequency is measured in the satellite and relayed to the MGS where the doppler shift, time stamp, and therefore location, of the beacons can be computed by PRC software.

GLOMR GROUND STATION (MGS)

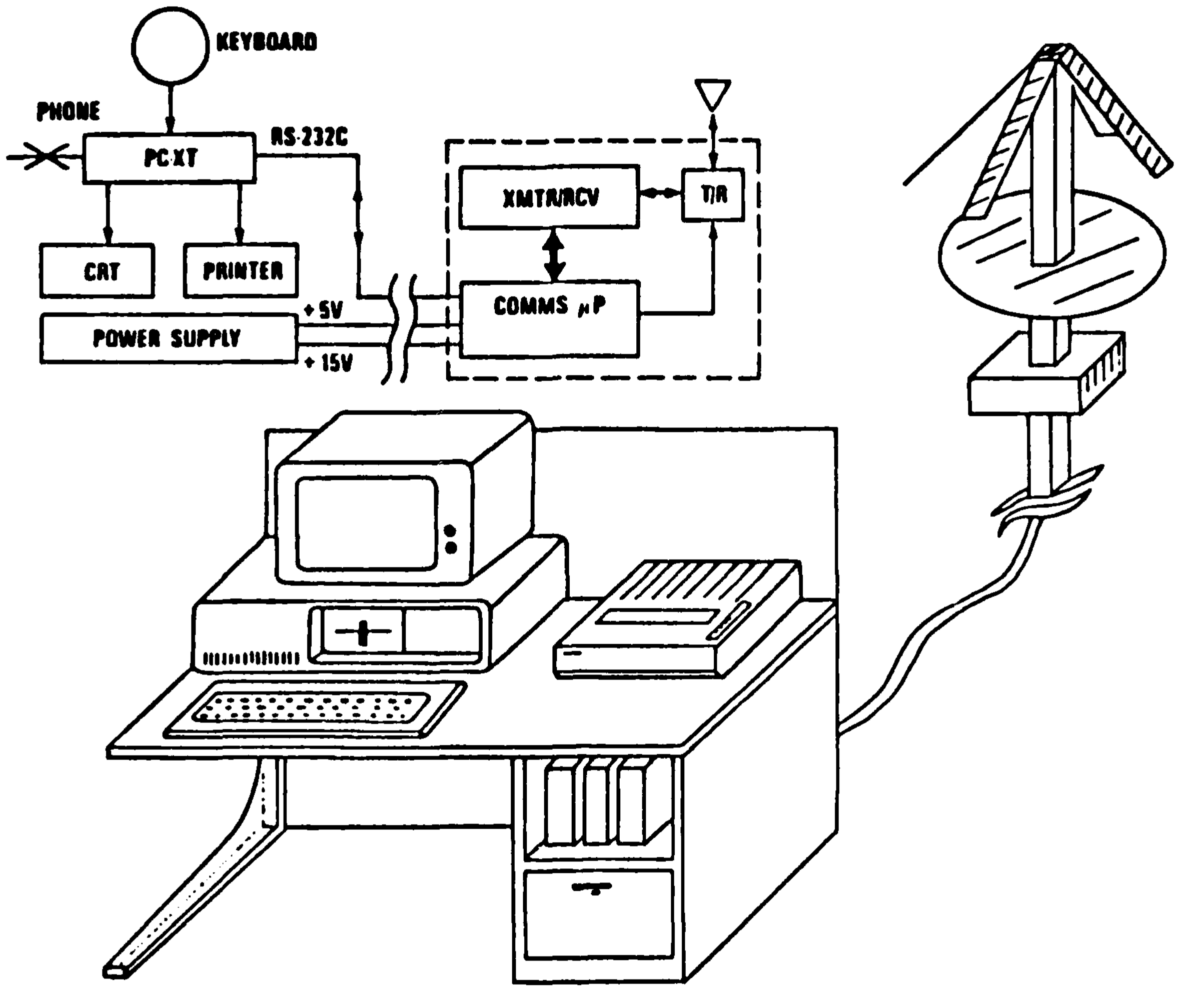


Figure 4-3. Master Ground Station Block Diagram

4.8 Task 5.1 - Integrate mission planning. The mission planning functions include orbit prediction from NAVSPASUR ephemeris, and the display of orbit paths overlaid on a world map. In addition, the MGS duties of proper mission planning include schedule generation, message preparation, uplinking and downlinking, message decoding and display. This task has been successfully exhibited by providing well planned and executed demonstrations to user/customers of the satellite system. Future plans include the integration of the PRC geolocation software into this MGS.

4.9 Task 6.1 - Demonstrate PET message. Demonstration of the PET message capabilities has been one of the most successful main activities of this contract. Figure 4-4 is a list of message and geolocation demonstrations. For the initial demonstration to DARPA, a test message was uplinked from the MGS; the PET was carried to the DARPA Headquarters in Rosslyn, Virginia and the message was downlinked (see the test plan at attachment 2). A typical scenario for a message demonstration is as follows. The time of the demonstration, and the preceeding uplinking of test messages and schedules, are determined from a pass opportunity schedule printed out by the DSI mission planning software. The satellite is scheduled to poll the MGS/PET at demonstration time. A message greeting the audience is uplinked on a previous orbit before the demonstration; see Figure 4-5 for typical messages. A test plan and a briefing are prepared and given to the audience; see attachments 2 and 3. At the time of the demonstration pass, the audience is gathered around the MGS or the PET, depending on location, to see the message downlink. This task is complete. Additional users/customers, such as the Atomic Energy Commission, have requested demonstrations of both message relay and geolocation.

4.10 Task 6.2 - Write message mailbox handler. Since the number of communications terminals has not been expanded beyond the MGS and the PET, the number of messages that need to be "handled" have been minimal. Therefore, the incoming messages at the MGS are downloaded, tagged and logged properly by hand, with no special software

Name	Place	Dates	Type	Uplink	Downlink
DARPA	Hq DARPA, Rosslyn, VA	04Jun86	Msg Relay	MGS	PET
Coast to Coast	PRL, Carpinteria, CA DSI, McLean, VA	10Jul86	Msg Relay	PET/MGS	PET/MGS
ONR	DSI, McLean, VA	10Sep86	Msg Relay	MGS	MGS
Army Action Officers	DSI, McLean, VA	16Sep86	Msg Relay	MGS	MGS
US Customs Service	Wash. Monument Washington, DC	17Sep86	Geolocation	Beacon	MGS
Army General Officers	DSI, McLean, VA	18Sep86	Msg Relay	MGS	MGS
Army Special Forces	Ft. Bragg, NC	24Sep86	Msg Relay	PET/MGS	PET/MGS
US Customs Service	El Paso, TX	01Oct86	Geolocation	Beacon	MGS
US Customs Service	San Diego, CA	02Oct86	Geolocation	Beacon	MGS
Army Space Program Office	DSI, McLean, VA	06Oct86	Msg Relay	MGS	MGS

Figure 4-4. List of Message Relay and Geolocation Demonstrations

GLOMR TYPICAL MESSAGES

USER	MESSAGE
NAVY -	Urgent, Proceed FS To Contact Position X and Y.
ARMY -	Radiation Reading Of ZZZZ, Monitor 9805, 1830Z
CUSTOMS -	Expect Large Shipment, Indian River Inlet 10/28/AM
JUSTICE -	Surveillance Target Now Leaving NY Area
DARPA -	Contract Has Vital Defense Value For Nation

Figure 4-5. Typical GLOMR Messages

program for mailbox handling being required at this time. The PET operator manually assigns a unique receive file name, or mailbox, for each user which has proven to be totally satisfactory for the present system.

4.11 Task 5.3 - Generate mission planning demonstration displays. Mission planning displays have been used to produce pass plots for all demonstrations. See Figure 4-6 for an example of a pass plot produced by the PRC GEODE software. Additionally, DSI has the ability to produce displays and pass plots on a world map background using their integrated MGS/Mission Planning software. This DSI software runs on an IBM PC and produces a color map of the world with the satellite path overlaid. It can be run in either a predictive mode or real time mode. The predictive mode is used to generate pass opportunity schedules. The real time mode is used during demonstrations to give visual and audible cues for pass rise time and set time. The real time display was successfully used in an outdoor "field" demonstration at Fort Bragg, where the portable personal computer was operated out of the trunk of a car. A hood was placed over the CRT to screen the sun so the audience could see the display. This task is completed, and the software is available to rapidly produce screen and hard copy displays for any future demonstrations.

4.12 Task 4.2 - Install PET geolocate calculator. The task initially called for the installing of a geolocation calculator in the Portable Earth Terminal (PET). However, initial analysis showed that the TRS-80-100 computer, that is being used in the PET, was not a suitable candidate for a geolocation calculator because of memory limitations. Also, a decision was made to rehost the MGS software on an IBM PC compatible computer, which makes it a better choice for the installation of PRC developed geolocation software on this new computer.

4.13 Task 6.3 - Integrate/test beacons. The task to integrate and test the beacons has been completed. The beacon acceptance tests were performed August 12 and 13 at the

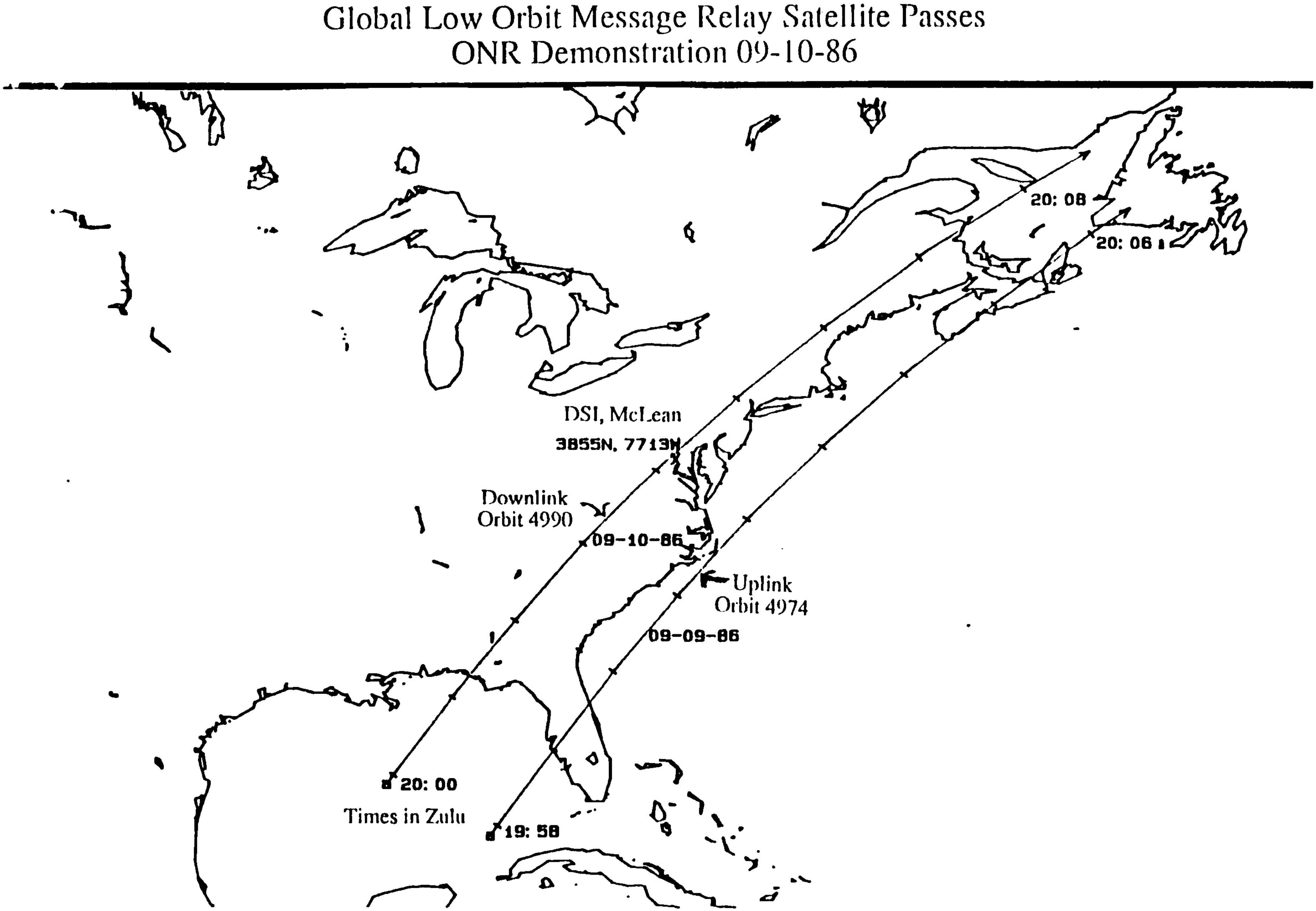


Figure 4-6. GEODE Pass Plot

vendor's plant in Richmond, Virginia and initial data indicated that the beacons had worked perfectly, and the complete GLOMR geolocation system had produced acceptable data. However, a planned series of geolocation tests, covering a six week period of time, failed to produce any consistent downlink data. This was due to a number of satellite and ground station technical and operational errors. Additionally, the beacons were successfully "bench tested" with a prototype copy of the satellite to better understand any anomalous behavior. The MGS antenna was connected to the prototype satellite and the beacon transmitted over the air to it. Bench tests of beacon number two showed that the termination "latch" that was to signal the end of a transmission may not be signaling correctly. Therefore a new latch chip was installed to insure a correct transmission termination. This had no operational effect however, because beacon number two was never used in any of the operational tests and demonstrations. Beacon number one, the one used operationally, worked perfectly in the bench tests and throughout the test and integration period.

4.14 Task 5.2 - Write planning macros. The writing of planning macros was handled similarly to the geolocation calculator. A review was made of the PET computer (TRS-80-100) and the conclusions were that the simplicity and inefficiencies of the computer did not warrant the programming effort for planning macros in the PET. The planning macros were then included in the effort to rehost the MGS on an IBM PC compatible computer. This accomplished the task and brought together most of the planning and demonstration hardware and software in one central location.

4.15 Task 4.3 - Analyze DSI data for geolocation. Three or more "clockings" are required in a given satellite pass to do geolocation of a stationary target. Even more are required for a moving target. Figure 4-7 shows the geolocation concept. Since neither the MGS nor the PET were designed to transmit multiple long duration contacts (6 or 7 seconds) during a pass, beacon transmitters were designed and procured by ARDAK to

GEOLOCATION CONCEPT

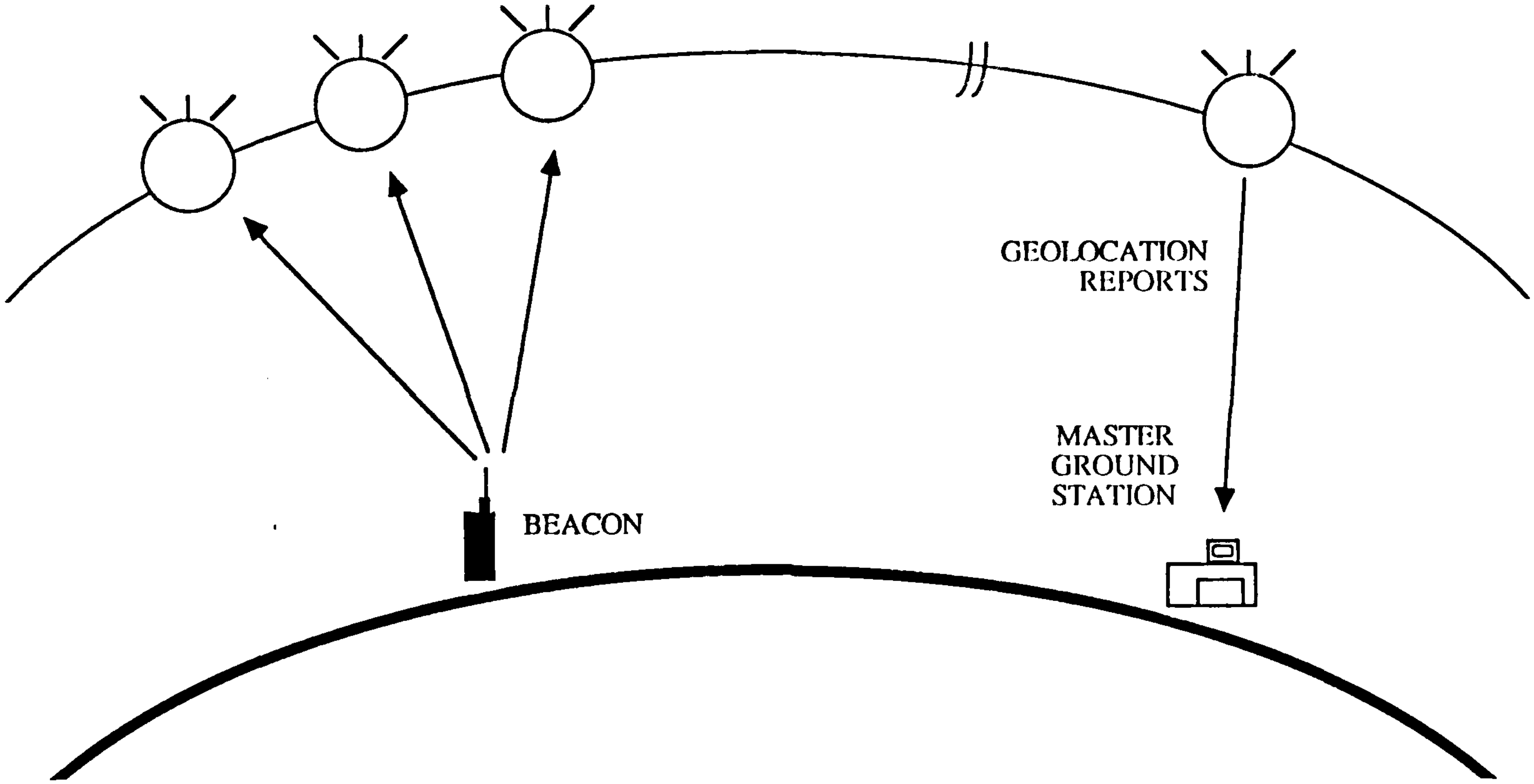


Figure 4-7. Geolocation Concept

basic emitters for geolocation. Up until mid-August, when the beacons were delivered, there were no consistent data which could be used for geolocation analysis. Software and synthetic data available from other satellite programs were therefore used in the analysis. This data was aided by occasional single examples of raw geolocation data received by the MGS, where its transmissions had been long enough to be "clocked" by the satellite. Figure 4-8 shows geolocation data as it comes out of the Master Ground Station.

4.16 Task 4.4 - Test geolocate capability and analyze. The initial ability of the satellite to "clock" the beacons during their acceptance tests was hailed by many interested GLOMR users as real success. ARDAK then detailed a series of geolocation tests which would begin with an initial clocking, and progress to three or more contacts in a single pass. A typical scenario is as follows. The MGS is used to schedule the satellite to poll the beacon during a pass selected from the pass opportunity schedule. At the time of the pass, the beacon operator finds an area that is free of obstructions and listens for the satellite poll using a commercial receiver. Following the poll "beep", the operator keys the transmission sequence of the beacon to start. The sequence consists of a normal header frame and six seconds of empty "frames" which gets the attention of the satellite and synchronizes the satellite receiver clock. This is immediately followed by one "terminator" frame which signals the end of transmission to the satellite. This sequence constitutes one contact. Numerous examples of one, two and three such contacts were attempted during a pass as part of the test series. Unfortunately, the test series experienced a rash of problems that kept the integration contractor from obtaining any consistent geolocation data. ARDAK was able to test the entire capability of the GLOMR satellite system, and analysis was made of the test data. Examples of the problems which have prevented geolocation success include:

```
GEOLOCATION  DATA

Type ID        7
ODAC           2
DDAC           1
Geolocation ID     2
Geolocation Count 21
Geolocation Time 85/11/03  00:14:04
    1,  0  50 188  37,  0  50 188   4,  0   5  52 241  89 219,
Success Flag   IF Freq     Local Oscillator          Time
                                Frequency
       **************
```

Figure 4-8. Master Ground Station Geolocation Output

- On board processors take minutes to digest the data during limited pass time. If a second contact is initiated while the processors are still working, all the data are rejected.

- Signal fadeout at the end of a pass. Normal contact and sequence of contacts is initiated, but the ground emitter signal is lost (e.g., due to an obstruction) before a final termination frame is received by the satellite. This causes the satellite to wait for a period of time (minutes) for a termination signal and then think there is an on-board software logic problem and reset the satellite clock back to day one. It would often take many operational days to reset the clock and system for normal operation again.

- Satellite filters not able to handle rapid change of doppler frequency, particularly at time of closest approach when the doppler shift changes rapidly and reverses. The filters had been changed in the MGS which helped to increase the message throughput, but the satellite filters continued to be a system limitation, especially in geolocation.

- Failure of the MGS operator to schedule properly and have the satellite poll at the designated time or to have the MGS listen for the downlink.

- Weather damage to MGS equipment on the roof of the DSI building included lightning, rain and condensation in switches and relays.

It is important to understand that these problems are not insurmountable. ARDAK is looking forward to opportunities to continue the test and demonstration program. The GLOMR system has functioned on an end-to-end basis and results have been achieved. Additional time for tests and demonstrations should see good results on a consistent basis.

4.17 Task 6.4 - Integrate operations segments. DSI has integrated their mission planning software and MGS operations software on an IBM PC implementation of the MGS. This includes the mission planning displays of a color world map with GLOMR tracks overlaid on it. This display was demonstrated in real time at Fort Bragg, North Carolina in a "field" mode as well as being a basic part of many demonstrations that took place at the DSI building in McLean, Virginia.

4.18 Task 6.5 - Demonstrate GLOMR system. Demonstrations of the GLOMR system have included message relay and geolocation events for a number of interested users of GLOMR's capabilities. The message relay demonstrations performed at DSI used the MGS for both uplink and subsequent downlink; the demonstrations done remotely from DSI used the PET as one terminal and the MGS as the other terminal, with either/both performing uplink and downlink. During the Coast to Coast tests and demonstration, for example, the PET was used to both uplink and downlink messages, sometimes during the same pass. The Coast to Coast demonstration consisted of a specific message being uplinked from the PET in California and downlinked from the satellite to the audience of users around the MGS in Virginia. The message, which contained greetings to members of the audience, was received successfully. The geolocation demonstrations used a beacon to uplink and the MGS to downlink. Attachment 2 is the test plan for the first DARPA remote message relay demonstration. Attachment 4 is a test plan for message relay demonstration from DSI to DSI which was conducted for senior Army officers and others including retired Army Chief of Staff, General S. Meyer. Attachment 5 is a test plan for a remote geolocation demonstration which took place at San Diego, California for senior field officials of the Customs Service.

While the demonstrations have largely been deemed successful, and have generated much interest from the user community, the number of failures in both the series of tests and demonstrations need to be examined in greater detail. Attachment 6 is an

anomaly report that specifically covers the time from the West Coast tests (8 July 1986) through a series of geolocation tests which resulted in a lack of consistent data (12 September 1986). This report shows examples of technical problems with the spacecraft (clock reset) and ground equipment (rain damage); operational problems (local interference) and procedural/human errors (missed contact). ARDAK and Defense Systems Inc. have reviewed these anomalies and a section attachment 6 reviews specific limitations and lists action areas that are needed to correct the anomaly along with suggested system refinements. This task is complete. However, additional message relay and geolocation demonstrations are still desired by potential user/customers, such as US CENTCOM and the Atomic Energy Commission. Additional opportunities may be forthcoming where demonstrations can be continued during the life of the satellite, and results (potentially geolocation) can be added to this successful GLOMR satellite Applications Development effort.

4.19 Task 2.3 - Write final report/briefing. The task to write a final report is completed with the delivery of this report. A final briefing will be delivered to ONR and DARPA, and other user/customers as requested. Copies of briefing charts will be available at the briefings or may be requested.

5. CONCLUSIONS

Low orbiting, inexpensive satellites for communications and other spaceborne missions are receiving renewed interest. This is especially true as the trend continues in geosynchronous satellites towards increased size and cost. Budget restraints in programs and systems are forcing users to lower costs and simpler mission solutions. Other advantages of low orbiting satellites are that they are more dynamic, less susceptable to jamming and synergistic with modern packet switched data networking systems.

The Global Low Orbiting Message Relay satellite was a successful proof-of-concept vehicle, that operated satisfactorily beyond its initial orbital lifetime estimate. The ARDAK Applications Development contract was also successful in demonstrating the capabilities of this type of satellite with its simpler system objectives. The GLOMR satellite was never designed to do sophisticated geolocation, and it was certainly optimistic to expect the present satellite to accomplish such a task. Nevertheless, the program goals and objectives were met, with detailed mission planning, appropriate hardware and software development, and testing and demonstration of those developments to an interested user/customer community. The final success is the knowledge that the user community is presently planning and budgeting for follow-on spacecraft and systems.

6. RECOMMENDATIONS

A series of recommendations and suggested improvements have resulted from this GLOMR Applications Development effort. These will be detailed first as they apply to the overall system, then to the Master Ground Station and portable ground equipment.

6.1 Low cost satellite systems are required by a user/customer community that is experiencing budget realities. However, this community is accustomed to higher communications throughput, for example, and more user friendly operations. Even when the present system was introduced as experimental or proof-of-concept, real frustration was expressed over lack of throughput and inability to conduct geolocation demonstrations. Therefore, future GLOMR type spacecraft and systems need to adhere to low cost goals and objectives, but additional attention needs to be provided in the areas of design, fabrication, and testing to improve operational efficiency and user satisfaction. Additional attention to user requirements will also assist in the validation of the basic system concept and insure stronger user support.

6.2 Additional study is required on mission requirements, specifically how inexpensive, low orbit satellites can fill voids in present geosynchronous systems; or how specific missions can best be met using GLOMR satellites. Some schools of thought are to make the next generations of GLOMR type satellites esoteric with only a few specific users and missions. Others schools want future GLOMR satellites to rapidly become compatible with many military and governmental missions and systems.

6.3 A trade-off study should be made on spacecraft versus ground terminal costs. Traditionally, inexpensive satellites were procured when the number of proposed users were small and thus ground equipment costs could be more expensive. However, if GLOMR type systems are proposed which use a large number of small, inexpensive data

gathering terminals, then more sophistication and cost should be put into the space segment for overall system economy.

6.4 Additional investigation is required on the spectrum or frequencies that may be available for GLOMR type systems. The use of only one frequency in this Applications Development effort was limiting, but understandable. Future pre-operational and operational systems must know how to best utilize available frequencies and plan for spread spectrum or other system options. Options like frequency hopping, spread spectrum, and encryption all need to be evaluated in relationship to proposed mission requirements.

6.5 Improved clock and system frequency stability are required if doppler geolocation is going to be part of the mission. With a satellite in a 350 kilometer oribt, the spacecraft velocity is about seven kilometers/second, so that a one second clock or end-to-end error could produce a seven kilometer position error.

6.6 Geolocation systems should consider ranging as opposed to the inverse doppler method. Ranging systems with space qualified chip technology exist, and have the advantages of: lower probability of detection, lower consumption of spacecraft power; allows more accurate geolocation, greater organic orbit determination; and, more users to access the system.

6.7 The Master Ground Station should be redesigned to improve its overall reliability, efficiency and ease of operation. Beginning at the top, the antenna could be directionalized to increase its gain and to limit and discriminate against local interference. A simple tracking device can be included as part of the antenna. The transmit and receive equipment needs to be packaged better which would not only provide protection from the natural elements, but also increase the temperature stability of the components. The computer and software functions have been greatly improved by the change from the DEC 11/73 to the

IBM PC system. Additional emphasis should be placed on automating the housekeeping functions to minimize operator supervision and control.

6.8 The Portable Earth Terminal, as initially designed, is clumsy and inefficient in both hardware and software components. DSI has undertaken the development of a handheld replacement, under another contract, and it has the potential to solve many of the original shortcomings. Questions of frequencies, modulation schemes, compatibility with other military ground user equipments and standards need to be investigated in future studies.

GLOMR BIBLIOGRAPHY

1. Beacon Operations Manual, ARDAK Corporation, August 1986

2. GEODE User's Manual, Planning Research Corporation, January 1986

3. "Get Away Special (GAS) Small Self-Contained Payloads", Experimenter Handbook, National Aeronautics and Space Administration, Goddard Space Flight Center, Sounding Rocket Division, October 1979

4. GLOMR Master Ground Station (MGS) User's Guide, October 1985

5. Ground User's Terminal (GUT, PAT or PET) User's Guide, Defense Systems Incorporated, October 1985

6. GLOMR Portable Access Terminal User's Guide, Defense Systems Incorporated, Document No. 401273-1

7. "Multiple Satellite System Study", Final Technical Report, M/C-Com Linkabit, Incorporated, February 20, 1985, Naval Electronics Systems Command Contract No. N0039-81-C-0639

8. Schmid, Paul E., Jr. and Lynn, J.J., "Satellite Doppler - Data Processing Using a Microcomputer", IEEE Transactions on Geoscience Electronics, Volume GL-16, No. 4, October 1978

9. Standard 7935 - Automated Data Systems Documentation Standards, Department of Defense

Attachment 1

ARDAK CORPORATION

GLOMR APPLICATIONS DEVELOPMENT WORK PLAN

17 APRIL 1986

ARDAK CORPORATION • 1493 CHAIN BRIDGE ROAD • SUITE 302 • MCLEAN • VIRGINIA • 22101 • (703) 893-3702

1.0 Introduction and Summary

1.1 Objectives and Perspective

The primary objective of this effort is to develop for DARPA a full understanding of the "GLOMR" (Global Low-Orbiting Message Relay) satellite capabilities and their future potential for application to a variety of U.S. Government missions. A secondary objective is to develop a potential user base for future low-cost message relay and geopositioning satellites.

1.2 Problem Statement

Now that on-orbit operation of GLOMR and its Master Ground Station (MGS) have been initially demonstrated, the current utility of this low cost satellite and the potential for its application to a number of U.S. Government activities needs exploration. However, the initial DARPA contract with the GLOMR developer, Defense Systems, Inc. (DSI), included only limited task coverage for initial operations. The scope did not foresee the unavoidable launch delay that exhausted contract funds.

GLOMR's lifetime is known to be limited based on its low-altitude orbit, which causes atmospheric drag and leads to unavoidable orbital decay. Because of unpredictable atmospheric anomalies, the lifetime may be reduced, but as currently predicted end of life will occur in September 1986. As a result, the activities described herein to exercise all capabilities and develop a full understanding of the system will be initiated as soon as possible. In addition, a work plan strategy will be to integrate, test and demonstrate the system capabilities rapidly, leaving most of the data analysis and evalution to the end of the program.

Although development of DARPA's knowledge base about GLOMR applications needs the involvement of potential users, sophisticated long-term demonstrations are not within this current contract scope. Without such user reactions and progressive thought contributions about the needs for a low-cost message delivery and geopositioning capability, the Government may not have the required data to adequately assess the

ARDAK CORPORATION • 1493 CHAIN BRIDGE ROAD • SUITE 302 • MCLEAN • VIRGINIA • 22101 • (703) 893-3702

opportunity to develop a low-cost space system that uniquely satisfies specific missions while greatly reducing expenses.

1.3 Project Objectives

ARDAK will develop new software and processes which facilitate clear and complete demonstrations of the GLOMR system. Because of the existing DSI experience base, ARDAK will subcontract to DSI those tasks which are closely related to the operation of the MGS and the satellite itself.

The developments and demonstrations included in this effort will be based on a thorough knowledge of existing software to minimize cost and schedule. ARDAK requires that existing current versions of PRC source code for mission planning, and DSI source code for all operational software be made available as machine-readable form with annotated listings as GFE to ARDAK. It is also required that ARDAK have access to the DSI Master Ground Station (MGS) and Portable Earth Terminal (PET). We require that this software and hardware be accepted by the Government and bailed (or other access arrangement) to ARDAK within 10 days of project start date.

The GLOMR earth terminals presently are comprised of one Master Ground Station (MGS) and a Portable Earth Terminal (PET). ARDAK expects to receive small, one-way beacons for geopositioning, and a transceiver for convenient message delivery.

Based on the extensive experience with the GLOMR system over the past year, ARDAK will now:

- complete development and integration of required software;
- thoroughly exercise GLOMR with a variety of users with GLOMR's attendant ground support systems;
- stimulate user response by demonstrating GLOMR capabilities;
- document all previous mission situations and tests, and findings of all on-going tests, demonstrations, and potential operations.

2.0 Technical Approach

ARDAK will accomplish the six main tasks shown in Figure 2-1 as follows.

2.1 Task 1 - Management

Objective: Ensure that technical, cost, and schedule requirements are met.

2.1.1 Task 1.1 - Project Planning. This task includes the on-going monitoring of work starts, periodic progress reporting to DARPA, and resource/technical direction. The development and updating of this work plan falls under this task.

2.1.2 Task 1.2 - Contract with DSI. ARDAK will negotiate a subcontract with DSI covering the tasks best suited to DSI within contract funding/time constraints. ARDAK will work closely with DSI and monitor their progress.

2.1.3 Task 1.3 - Contract with PRC. As in Task 1.2, ARDAK will negotiate a subcontract with PRC and work closely with them.

2.2 Task 2 - Data

Objective: Develop quality documentation for delivery to the Government.

2.2.1 Task 2.1 - Document Current DSI Work. This is basically a detailed planning task in which ARDAK will prepare a complete report of past and present operational situations and anomalies, developing details of requirements for subsequent tasks.

2.2.2 Task 2.2 - Write GLOMR-to-PET Interface Spec. In order to competitively acquire small GLOMR transceivers and beacons from companies with experience in this field, a clear and detailed satellite interface specification is required. ARDAK, in collaboration with DSI, will generate this specification and quickly circulate it among known vendors. The medium and long-term program benefits of preparing good interface specifications and making these known to qualified vendors are very real. The present satellite lifetime restrictions, however, limit normal procurement schedules and the amount of useful design and hardware response that are normally expected in hardware development efforts. Therefore, this test and demonstration will maximize the use of

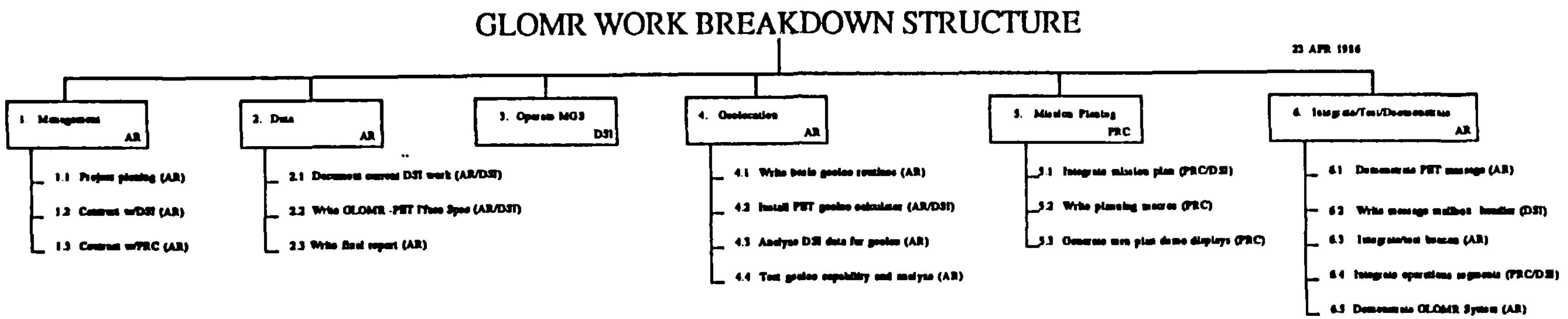


FIGURE 2-1. GLOMR Work Breakdown Structure

ARDAK CORPORATION • 1493 CHAIN BRIDGE ROAD • SUITE 302 • MCLEAN • VIRGINIA • 22101 • (703) 893-3702

present MGS and PET terminals, and will use the interface specification to procure, and if need be modify, off-the-shelf beacons.

2.2.3 Interim Reports. ARDAK will prepare monthly Interim Reports that will describe the status of the GLOMR system and of the contract. The reports will set forth the milestones and tasks that are completed along with the progress of those currently underway.

2.2.3 Task 2.4 - Write Final Report. ARDAK will review, analyze, assess, and report on demonstration results and user responses. This effort will provide for reporting user interactions, comments and requests for changes, analysis and aggregation of these with respect to how the system functions, and results to form a basis for upgrades. The task includes the preparation of a final report which documents the advances and the anomalies discovered during the project with recommendations for improvements, and includes an analysis of observer/user reactions.

2.3 Task 3 - Operate MGS

Objective: Reduce required manpower for daily MGS operations and perform station keeping.

The continuing MGS operations will be conducted by DSI personnel as the following subtasks.

a. Plan and execute "full event" contacts every pass. This subtask provides for operations of scheduling, message preparation, orbital pass determination, telemetry readout and analysis, and post-pass closeout and record-keeping.

b. Plan and execute "simple events" for later delivery. this subtask provides for minimum support of any operations event such as a pre-planned message delivery pass.

c. Conduct link margin measurements and calculations. This subtask provides for the critical understanding of RF link performance. Future satellite models will use this data for major design decisions such as energy storage capability and antenna polarization.

d. Support geolocation and Doppler shift experiments. This subtask provides for planning and uploading commands to measure frequency on-board the satellite so that geolocation activities can be performed. The task then supports the calculation of geolocation of users' terminals, and the required error determination experimentation involved.

e. Maintain complete operations documentation. This subtask provides for the maintenance of complete logs on every activity, including upload commands and downlinked telemetry, and overseeing health of the satellite, as well as message receipt, delay, and reply situations.

2.4 Task 4 - Geolocation

Objective: Develop and demonstrate a GLOMR capability to geolocate beacons and other GLOMR earth stations.

2.4.1 Task 4.1 - Write basic geolocation routines. Geolocation during operations of the portable earth terminal, beacon, and small transceivers requires the application of known theory, including Doppler, through special software. This software package development is ready for start-up, and when completed and tested will be the core of the future GLOMR geolocation operations.

2.4.2 Task 4.2 - Install PET geolocation calculator. The geolocation calculator similar to that derived for the MGS will be installed and tested in the Portable Earth Terminal (PET). Geolocation data will be analyzed and fed back to remove bias and system errors in data.

2.4.3 Task 4.3 - Analyze DSI data for geolocation. DSI records GLOMR data as it orbits. This machine readable data will be used to simulate inputs to the geolocation routines. Once testing and demonstration with pre-recorded data is completed, live GLOMR data will be processed and demonstrated.

2.4.4 Task 4.4 - Test geolocation capability and analyze. This is a continuation of Task 4.3 using live GLOMR data. The accuracy and applicability of GLOMR

ARDAK CORPORATION • 1493 CHAIN BRIDGE ROAD • SUITE 302 • MCLEAN • VIRGINIA • 22101 • (703) 893-3702

geolocation will be tested and analyzed for fixed and mobile targets, with and without known reference emitters. The preliminary estimates shown in Figure 2.4-1 will be refined.

2.5 Task 5 - Mission Planning

Objective: Increase automation of MGS operations.

The current MGS operations are labor-intensive and need increased automation. This task prepares new software to permit at least one week's mission predictions and command interactions to be carried out with a minimum of supervision.

2.5.1 Task 5.1 - Integrate DSI and PRC mission planning segments. A current effort at Planning Research Corporation (PRC) is developing mission planning software to permit development of needed prediction data, primarily in display form. These results will be integrated with the DSI software to enable improved operations and clear definition of tasks prior to satellite passes.

2.5.2 Tasks 5.2 and 5.3 - Mission planning displays and macro routines. For quick understanding in demonstrations of the system, screen displays for mission tasks, planning, and input/output requires new software. Function key entry will be facilitated by macro routines aggregating chainable tasks.

2.6 Task 6. Integrate/Test/Demonstrate.

Objective: Demonstrate the value of GLOMR to potential users.

This task brings together all of the capabilities developed under this contract. The necessary software, test plans, briefings and test reports will be developed.

2.6.1 Task 6.1 - Demonstrate PET message. This task covers the testing and demonstration of the existing PET message capability. This experience is prerequisite to developing and demonstrating all other capabilities.

2.6.2 Task 6.2 - Mailbox message handler. The mailbox message handler has been planned since the beginning of the GLOMR project. It will be a data file manager that greatly simplifies the transmittal of numerous messages -- a situation that becomes

WORST CASE LOCATION ACCURACY IN KM

DATA SOURCE	FIXED	BOAT (15 KNOTS)	AIRCRAFT (400 KNOTS)
DOPPLER	3 - 5	10.2 - 12.2	80
CALIBRATED DOPPLER	.6 - 1.0	8.5	80
RANGING	1.6	4.3	80
CALIBRATED RANGING	.4	4.0	80

FIGURE 2.4-1. Estimated GLOMR geolocation accuracies.

somewhat complex because of the GLOMR store-and-forward system. For even a modest number of users, there must be software available that can receive incoming messages, upload them at the right time, receive downloaded messages, and properly tag them for recipients. This software will be generated for message handling on the MGS computer, and on appropriate portable terminals.

2.6.3 Task 6.3 - Integrate and test new beacon and transceiver. This subtask provides for the testing and integration of the new user beacon/transceiver with the augmented GLOMR system.

2.6.4 Task 6.4 - Integrate DSI, PRC and ARDAK operations segments. This subtask will integrate the essential development efforts of the three contractors into final operations segments that can be demonstrated. In addition, this effort will provide graphic displays for easy understanding of the individual GLOMR functions and missions. The task also includes the integration of the planning "macros," -- short programs that chain together necessary commands and present them to a single function key -- to enable easy demonstrations to potential users.

2.6.5 Task 6.5 - Demonstrate GLOMR system. Demonstrate all capabilities. As all the former capabilities are completed and operational, this subtask will provide for demonstrations of all capabilities of the satellite system, particularly the portable ground systems. As a part of this task demonstration, reports will be furnished summarizing comments from observers and potential users. Demonstration plans and schedules will be coordinated with potential users including: DARPA, U.S. Navy, U.S. Customs Service, and the Department of Justice. Other potential users will be investigated and additional demonstrations will be scheduled if satellite health and demonstration schedules permit.

3.0 Task Flow Diagram

The Task Flow Diagram is shown in Figure 3-1.

4.0 Activity Schedule

The Activity Schedule is shown in Figures 4-1 and 4-2.

ARDAK CORPORATION • 1493 CHAIN BRIDGE ROAD • SUITE 302 • MCLEAN • VIRGINIA • 22101 • (703) 893-3702

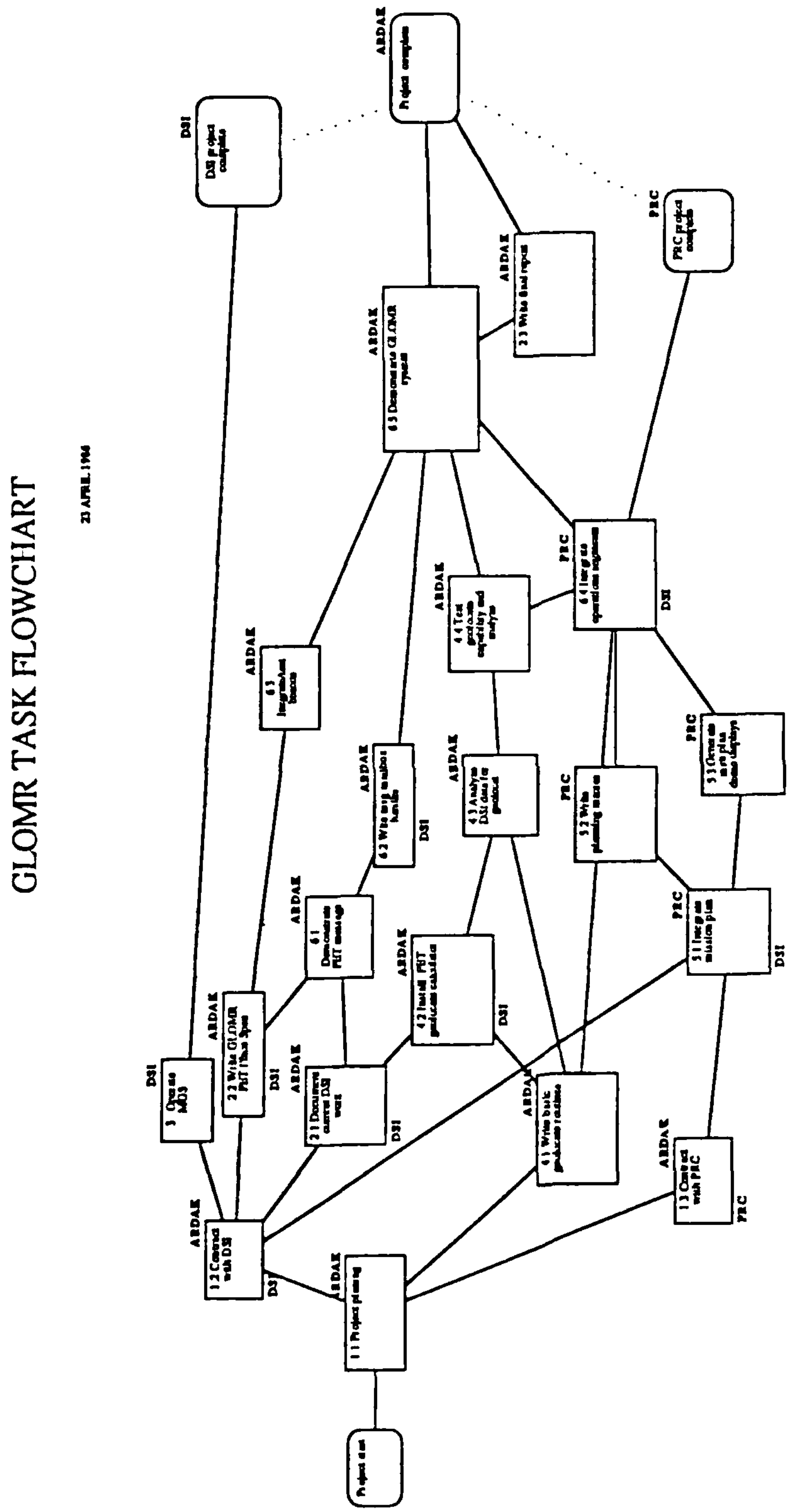
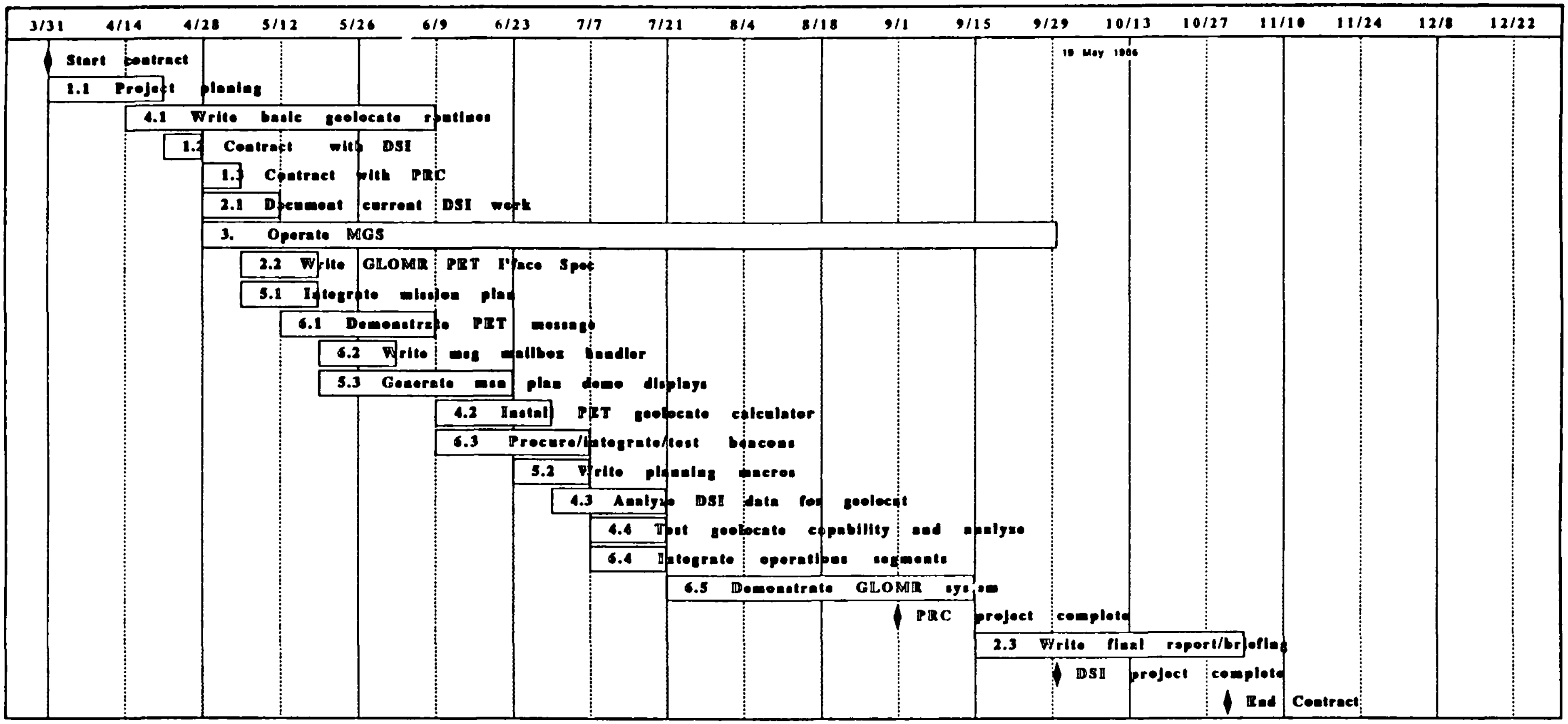


FIGURE 3-1. GLOMR Task Flow Diagram



FIRGURE 4-1 GLOMR Activity Schedule

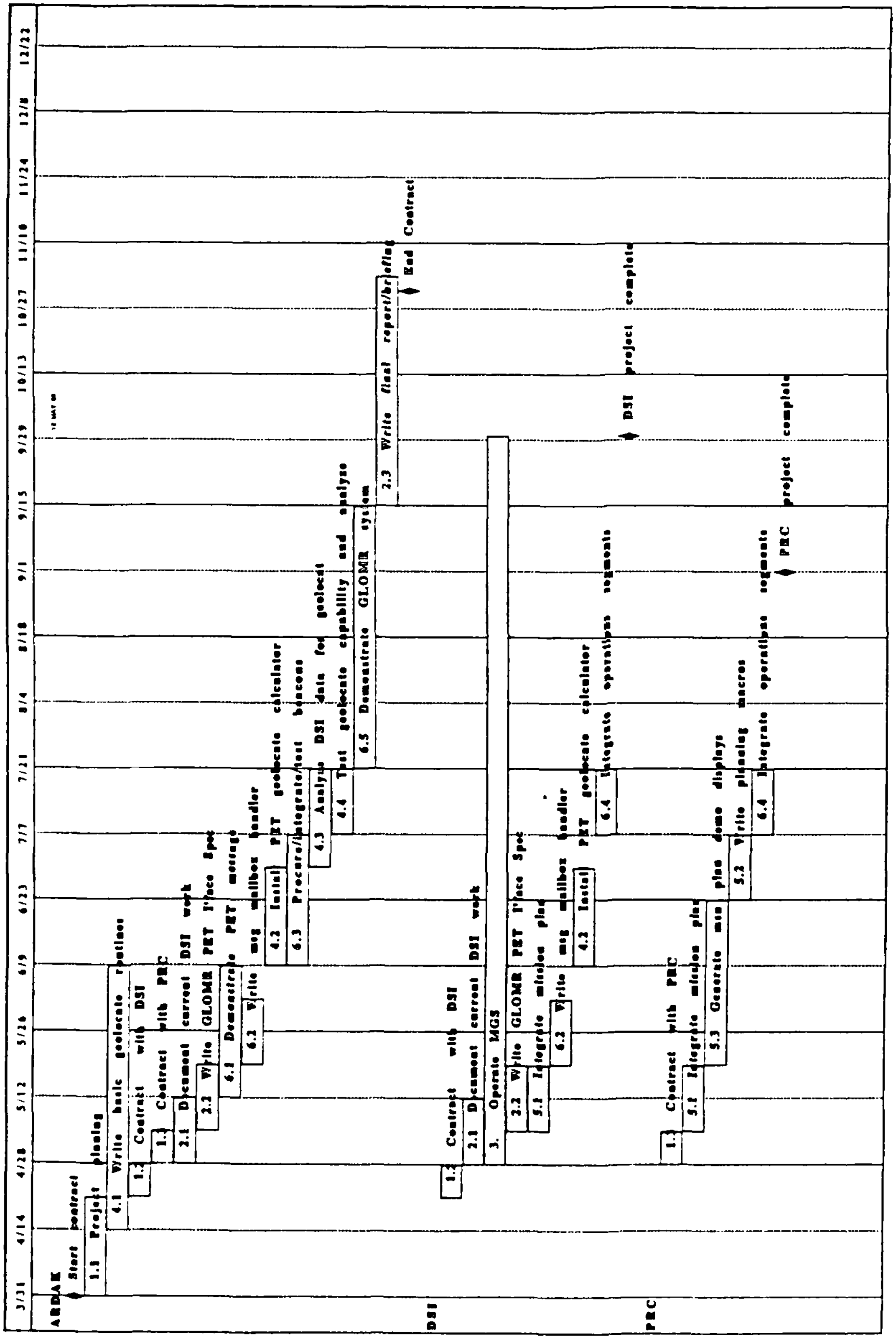


Figure 4-2. GLOMR Activity Timeline by Contractor

Attachment 2

GLOMR

TEST PLAN

for the

First DARPA Demonstration

10 June 1986

CONTRACT N00014-86-C-0330

Prepared by:
ARDAK Corporation
1493 Chain Bride Road, Suite 302
McLean, Virginia 22101

Prepared for:
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217-5000

SECTION 1. GENERAL

<u>1.1 Purpose of this Test Plan.</u> This test plan for Global Low Orbit Message Relay (GLOMR) demonstrations is written to fulfill the following objectives:

a. To coordinate an orderly schedule of events, equipment and organizational requirements, the methodology of testing, and a list of materials needed to support tests/briefings/demonstrations.

b. To provide guidance for the management and technical effort necessary throughout the test period.

c. To provide a written record of the actual test inputs, the instructions to permit execution of the test, and the expected outputs.

d. To communicate to the users the nature and extent of the tests deemed necessary to provide a basis for evaluation of the GLOMR system.

<u>1.2 Project References.</u>

a. DOD, Standard 7935 - Automated Data Systems Documentation Standards

b. DSI, GLOMR MGS User's Guide, Oct 85

c. DSI, Ground User's Terminal (GUT, PAT, or PET) User's Guide, Oct 85

d. PRC, GEODE User's Manual, Jan 86

1.3 Terms and Abbreviations.

ARDAK	The GLOMR system integration contractor
DARPA	Defense Advanced Research Projects Agency
DSI	Defense Systems Incorporated - the GLOMR hardware contractor
LCD	Liquid Crystal Dsiplay
GEODE	Graphic Earth Orbit Display Environment
GLOMR	Global Low Orbit Message Relay
GMT	Greenwich Mean Time
MGS	Master Ground Station - located at a DSI facility in McLean, VA
MPS	Mission Planning System
PAT	Portable Access Terminal, also called PET
PET	Portable Earth Terminal - a briefcase size message terminal
PRC	Planning Research Corporation
RAM	Random Access Memory
STO	Strategic Technology Office of DARPA
TRS	Tandy Radio Shack Corporation

SECTION 2. DEVELOPMENT TEST ACTIVITY

2.1 Statement of Pretest Acitivity. The following test activities have been performed prior to this test.

a. GLOMR hardware integration test. The GLOMR satellite was bench tested prior to launch.

b. MGS software integration test. The MGS was tested in the lab.

c. PET integration test. The PET hardware and software were tested in the lab.

d. MGS-GLOMR-MGS message test. Test messages were uplinked from the MGS and received back.

e. MGS-GLOMR-PET message test. Test messages were excanged via GLOMR from the DSI contractor facility.

f. DARPA site survey. The DARPA rooftop was visually inspected for field of view and accessability.

g. DARPA dry-run. Test messages were up-linked from the MGS and received by the PET at DARPA.

2.2 Pretest Activity Results. All of the above pretest activities, except for the dry-runs, have been performed successfully. A known limitation is the occasional loss of messages.

SECTION 3. TEST PLAN

3.1 System Description. The GLOMR system concept is illustrated in Figure 3.1-1. The system consists of:

- o One inexpensive satellite, GLOMR, in low earth orbit since October 1985
- o One fixed Mission Ground Station (MGS)
- o One portable, suitcase-size, Portable Earth Terminal (PET)
- o Two hand held Beacons (to be procured), and
- o Tracking and ephimeris update services provided by NAVSPASUR

3.1.1 The GLOMR Satellite. Figure 3.1-2 shows GLOMR and its dimensions. Its roughly spherical shape is made up of flat squares and triangles. The outside is ringed with solar cells. The antenna is omnidirectional; the radio operates at 287.4MHz transmit and receive. The satellite was launched from Shuttle flight 61A on 31 October 1985 with an inclinitation of 57.9 degrees. With the low orbit, useful passes last 5 to 10 minutes. The orbit period is roughly 90 minutes. Useful passes come in groups of three, followed by a 6-hour gap.

3.1.2 Mission Ground Station (MGS). The MGS is located at the Defense Systems Incorporated offices in McLean, Virginia. It consists of a DEC PDP-11 Minicomputer, a transmitter and reciever identical to that inside the satellite, and an antenna. The software performs the following functions:

- o Compute pass time schedule from NAVSPASUR ephemeris
- o Create tasking for the satellite
  - e.g., schedule on/off times
- o Communicate with the satellite
  - build and send messages
  - receive and decode messages and telemetry

3.1.3 Portable Earth Terminal (PET). The PET is a suitcase sized terminal for sending and receiving GLOMR messages. The PET consists of a lap top microcomputer, the TRS-80-100, an antenna, and a transmitter and reciever identical to that in the MGS and the satellite. The computer and radio are housed in a suitcase sized carrying case. The microcomputer software allows the operator to create and send messages, and to receive and display incomming messages.

3.1.4 The Beacons. These are small transmitters used to test and demonstrate a capability to geolocate the transmitters. The beacons are hand held battery operated transmitters which send simple signals to the satellite. The doppler shift in these signals is computed and relayed to the MGS or PET where the location of the beacons is computed.

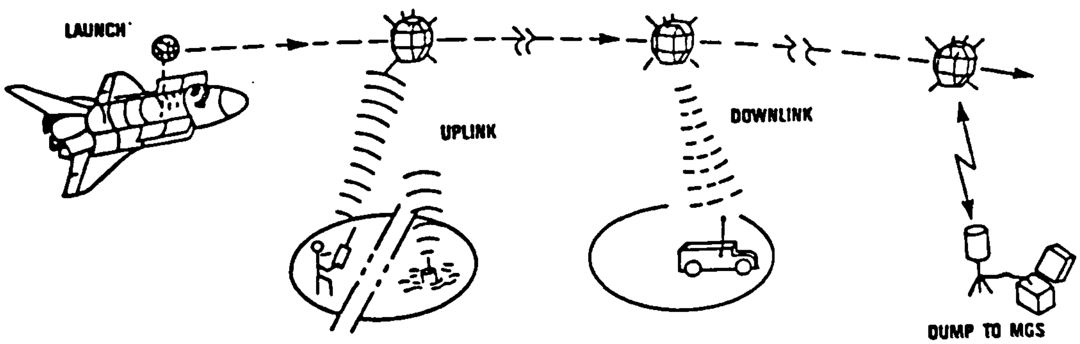


Figure 3.1-1. GLOMR System Concept

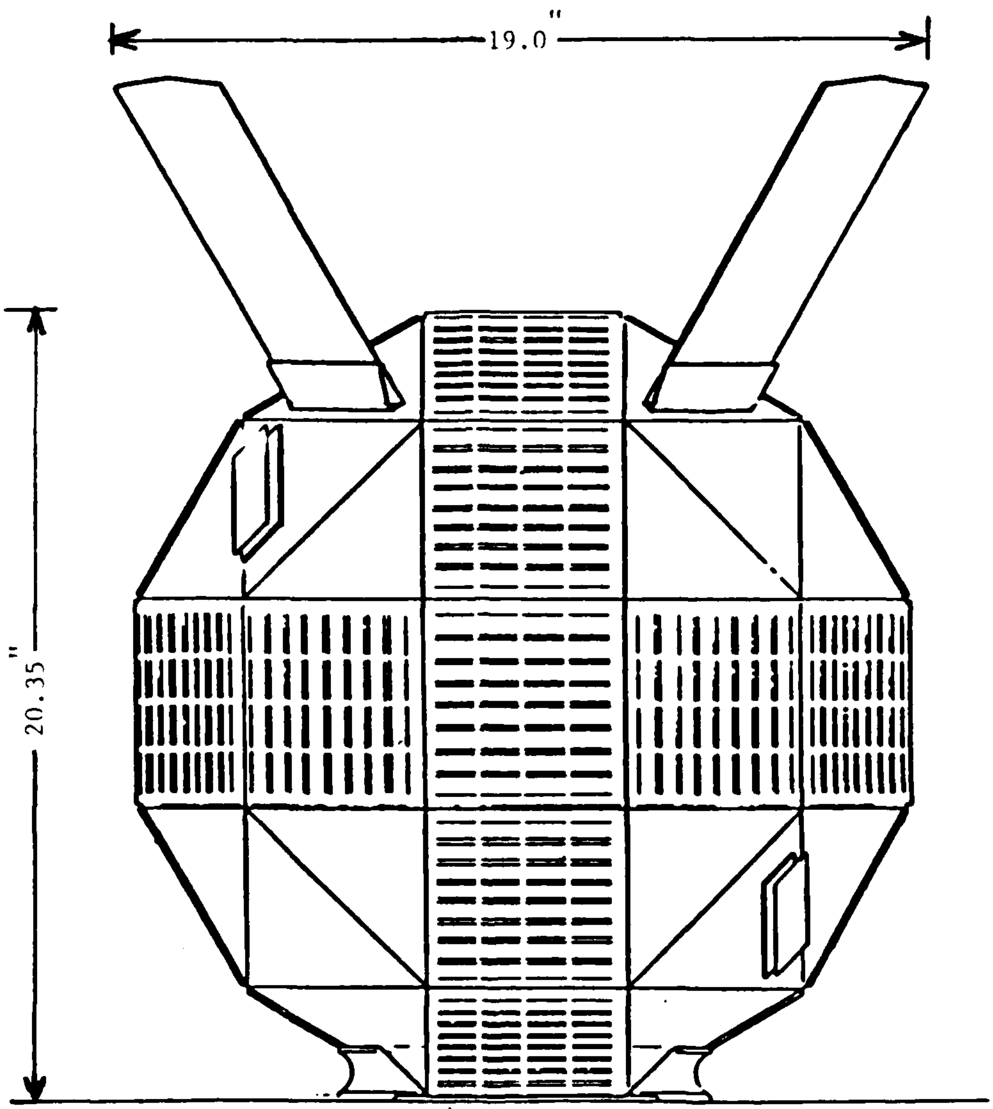


Figure 3.1-2. GLOMR Satellite

3.1.5 Tracking and Ephemeris. The Navy Space Survallence Command (NAVSPASUR), Dalghren, Virginia, provides ephemeris updates to DSI via Telex. The updates are used to project pass schedules. The time of the passes is needed to know when to turn on receivers and when to transmitt messages.

3.2 Testing Schedule. The GLOMR tests will be conducted during the period May 1986 to September 1986.

3.3 Test 1 - DARPA Demonstration. This test will be perfomed at Hq DARPA, 1400 Wilson Boulevard, Rosslyn, Virgina. This deomonstration was requested by Lt. Col. Brian Bell, DARPA, for the benefit of Dr. Anthony Tether, Director, DARPA Strategic Technology Office (STO). The demonstation will be performed by ARDAK Corporation, the GLOMR systems integration contractor, and DSI, the GLOMR hardware contractor.

3.3.1 DARPA Milestones.

24 May 86	Site survey at DARPA
27 May 86	First Dry-run at DARPA
03 Jun 86	Second Dry-run at DARPA
04 Jun 86	Demonstration at DARPA

3.3.2 Equipment Requirments.

a. The MGS at DSI will be used to uplink test messages.

b. The PET will be transported to DARPA and setup on the roof.

3.3.3 Software. All software being tested is part of the operational system. No special test software is needed.

3.3.4 Personnel. During the pre-pass briefing, personnel will be located as follows.

a. Rooftop	One PET hardware technician, DSI
b. Conference Room	(For the pass, all of these people will move to the roof to see the PET.)
Briefer	Mr. N. Helm, ARDAK
Audience	Mr. J. Gilchrist, ARDAK Mr. J. O'Neill, DSI Mr. J. Slack, President, ARDAK Dr. A. Tether, Director, DARPA/STO
c. MGS, in McLean	Dr. K. Reiss, DSI

3.3.5 User Orientation Plan. Since GLOMR is an experimental proof of concept system, the purpose of this demonstration is simply to orient potential program users to the capabilities and advantages of GLOMR.

3.3.6 Test Materials. Prior to the demonstration, test messages will be generated on the MGS and uplinked. For the demonstration, Vugraphs and a briefing board have been developed. The PET technician on the roof will bring the following:

- o Compass
- o Accurate watch
- o Umbrella
- o Sun Glasses

3.3.6.1 Deliverable Materials. Copies of the briefing and this test plan will be handed out. Since an operational capability is not being delivered, no technical user documentation will be delivered.

3.3.6.2 Site Supplied Materials. DARPA will provide use of:

a. Rooftop - for site survey, dry-run, and demonstartion.

b. Conference room with Vugraph projector and screen - for the demonstration.

c. Escorts as required by DARPA proceedures - for visiting personnel

3.3.7 Security and Privacy. The use of GLOMR is presently UNCLASSIFIED. The GLOMR system is not intended for the processing of data protected under the Privacy Act.

SECTION 4. TEST SPECIFICATION AND EVALUATION

4.1 Test Specification.

4.1.1. Requirements. This test will demonstrate satisfaction of the requirement to send messages via the GLOMR satellite, which includes the ability to uplink a message, store the message in GLOMR and forward the message to another ground station.

4.1.2 System Functions. The following functions will be exercised in support of this demonstration.

a. Satellite Tracking. NAVSPASUR provides updated ephimeris data twice weekly.

b. Mission Planning.

(1) Opportunity Schedule. The times when GLOMR passes over the MGS and DARPA are computed from the NAVSPASUR ephimerides. The demonstration and dry-runs are scheduled accordingly.

(2) Pass Plot. The PRC software, GEODE, is used to generate a computer plot showing the map of the U.S. overlaid with the selected in-view satellite passes.

c. Message Generation. Test messages are created on the MGS.

d. Message Uplink. The test messages are transmitted from the MGS to the satellite.

e. Message Store. The test messages are stored inside GLOMR until contact is made with the destination user.

f. Message Downlink. As the satellite passes DARPA, a scheduled command starts "beeping" the GLOMR transmitter. The PET responds to this contact and the messages addressed to the PET are downlinked.

g. PET Communications. The PET performs the required GLOMR handshaking, receives the message(s), stores them in internal memory, and displays the message to the users.

4.2 Data Recording.

Copies of all briefing materials will be made for inclusion in the test analysis report. ARDAK personnel will request user feedback on the demonstration and on the potential applications of GLOMR. These feedback comments will be incoporated in the test analysis report, and collected for the Final Technical Report, which will summarize recommendations for future system enhnacements and problem fixes.

4.3 Test Evaluation.

4.3.1 Test Data Criteria. The demonstration will be considered successful if the test message which was uplinked is received and displayed without error.

4.3.2 Test Data Reduction. System test output will be displayed on the PET TRS-80-100 screen, inspected visually, and manually copied down.

SECTION 5. TEST DESCRIPTION

5.1 Test Description. The prupose of this test is to demonstrate the GLOMR message capability. A test message will be uplinked form the MGS, stored in the satellite, and downlinked to the PET. The MGS is located in McLean, Virginia. The PET will be transported to DARPA and setup on the rooftop facing the azmituh of the pass. Prior to the pass, a short briefing will be given in the STO conference room. Then the audience will take the elevator and stairs to the roof where the PET is setup. As the satellite passes, the PET will communicate with GLOMR and store the test message in a buffer which will be displayed.

5.2 Test Control. The test will be initiated by manual means. The pass opportunity schedule gives the rise time of the pass; using a wristwatch, the PET operator will set the current GMT time and schedule the PET communications sequence. The PET will then automatically wait to be contacted by the GLOMR satellite. Once contacted, the PET and GLOMR automatically exchange handshaking signals, the GLOMR telemetry packet and any messages.

5.3 Test Data. Test messages will be created and typed into the MGS - see the MGS User's Manual, reference 1.2.b. The test message is:

TEAL RUBY: Eat your heart out. Good luck to Tony from GLOMR.

5.4 Input Commands. The PET operator enters the appropriate rise time (GMT) into the event table, EVTTABLE, using the system editor and then enters the following command sequence (see the PET User's Manual, reference 1.2.c):

Computer	Operator	Comment
MAIN MENU:	C <enter>	Communicate
SEND FILE NAME:	<enter>	None
RECEIVE FILE NAME:	RECEIVE <enter>	RAM file name
?DFIND-F-File not found		No file to send
Sending File		Ignore
Press any Key		Wait for contact
0000 bad blocks received		Contract made
	<space>	Reactivate main menu
MAIN MENU:	E <enter>	Editor
FILE:	RECEIVE	Display contents

5.5 Output Data. There should be three audible clicks from the PET antenna switch during the handshaking and message downlink sequence. The received message will be stored in a RAM file, called RECEIVE. Once recieved, the contents of RECEIVE are displayed on the TRS-80-100 LCD screen using the system editor. Since there is currently no printer connected to the TRS-80-100, the displayed message(s) will be copied manually. The display should resemble the following:

*ZPRSTQWP (telemetry line)

TEAL RUBY: Eat your heart out. Good luck to Tony from GLOMR.

5.6 Test Termination. The PET will be packed up and returned to DSI. The test will be discussed with the audience to answer any questions and to solicit user feedback on GLOMR and the demonstration itself.

Attachment 3

ARDAK

U.S. Customs Service

San Diego, CA

Global Low Orbit Message Relay

(GLOMR)

Satellite Briefing

02 October 1986

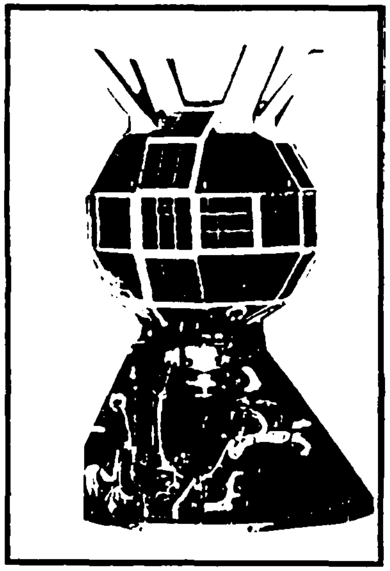
INITIAL GLOMR OBJECTIVES

- Cheap - Less Than $1M
- Designed and Built in Less Than One Year
- Initial Capabilities
  - Message/Data Relay
  - Geolocate/Track Beacons

GLOMR ORBITAL CHARACTERISTICS

Launch:	Shuttle Mission 61A
GLOMR Launch Date:	31 Oct 85
Launch Method:	GAS Can Spring Ejection
Seperation Velocity:	4 Ft/Second
Inclination:	56.98 Degrees
Launch Altitude:	175 NM
Period:	90 Minutes
Single Pass Visibility:	2 - 10 Minutes
	3-4 Consecutive Revolutions
	6 Hour Gap
Re-Entry:	Mid-Sep 86

GLOMR TECHNICAL CHARACTERISTICS



- Weight - 150 Lbs
- Diameter - 19.00" (Antenna Tips)
- Height - 20.35"
- Construction - 0.25" Brass
- Stabilization - None (slow tumble)
- Altitude Adjustment - None

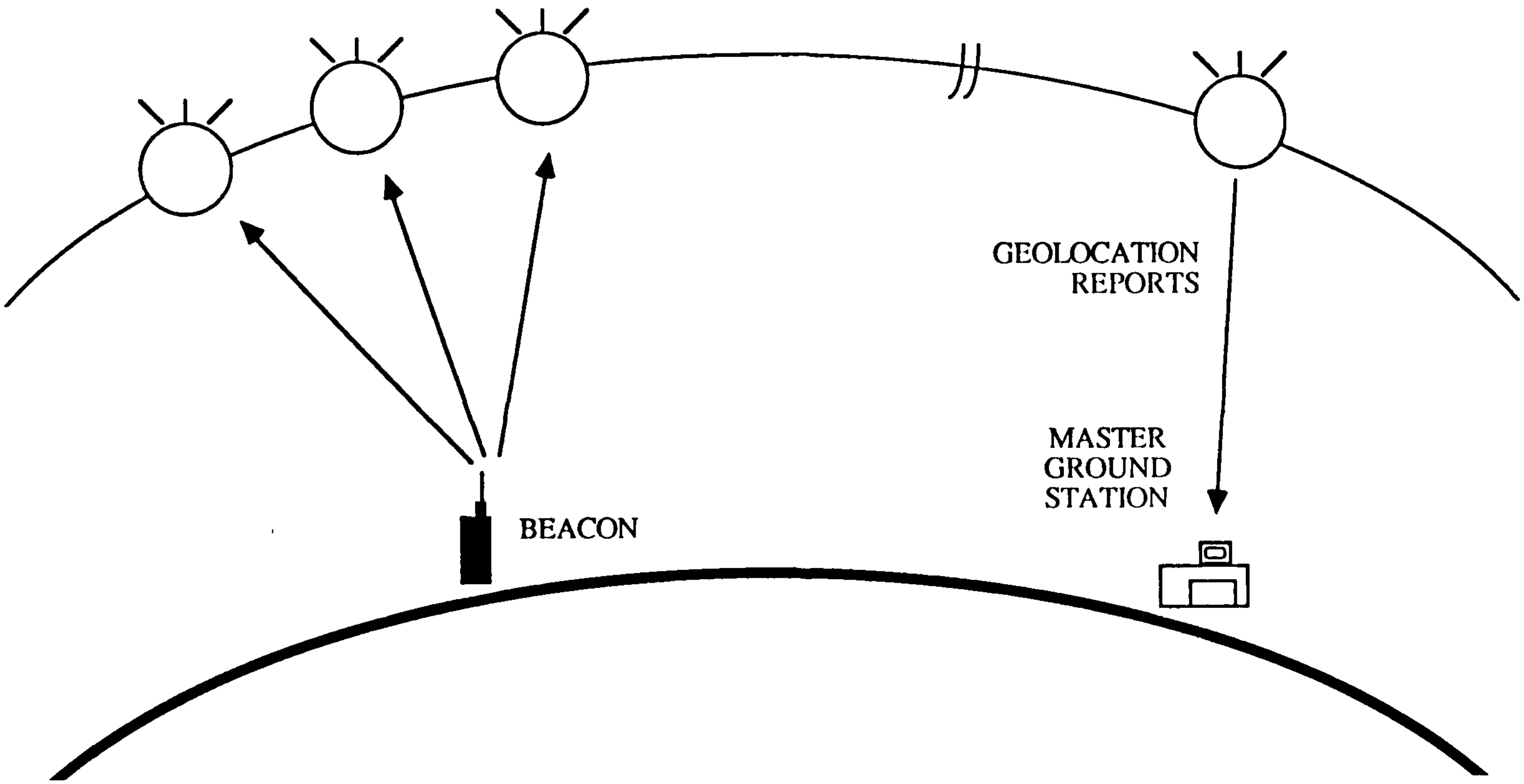
GLOMR OPERATIONAL CHARACTERISTICS

- Prime Power - 12 Watts
- EIRP - 10 Watts
- Operating Frequency - 287.4 MHz Xmit & Rcv
- Transmission Scheme - BPSK, 1200 Baud
- Modem - Burst

INTERESTED PROGRAM PARTICIPANTS

- DARPA
- U.S. Navy
- U.S. Customs Service
- Department of Justice
- U.S. Army

GEOLOCATION CONCEPT



TEST PLAN CONTENTS

SECTION 1. GENERAL
- 1.1 Purpose of the Test Plan

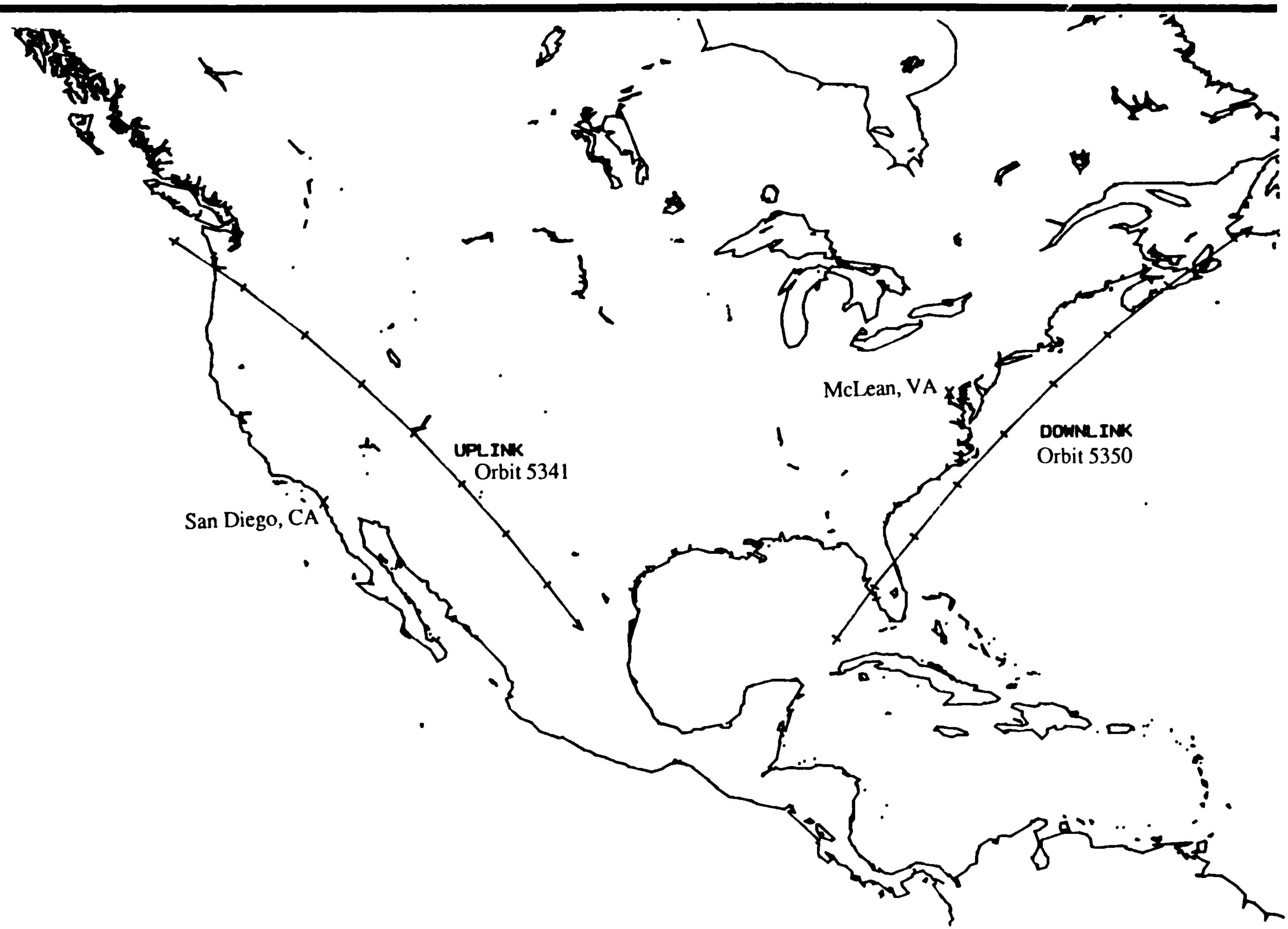
SECTION 2. DEVELOPMENT TEST ACTIVITY
- 2.1 Statement of Pretest Activity
- 2.2 Pretest Activity Results

SECTION 3. TEST PLAN
- 3.1 System Description
- 3.2 Testing Schedule
- 3.3 First Location (Identify) Testing
  - 3.3.1 Milestore Chart
  - 3.3.2 Equipment Requirements
  - 3.3.3 Software
  - 3.3.4 Personnel

SECTION 4. TEST SPECIFICATION AND EVALUATION
- 4.1 Test Specification
  - 4.1.1 Requirements
  - 4.1.2 System Functions
  - 4.1.3 Test/Function Relationships
- 4.2 Test Methods and Constraints
  - 4.2.1 System Test Conditions
  - 4.2.2 Extent of System Test
  - 4.2.3 Data Recording
  - 4.2.4 System Test Constraints
- 4.3 Test Progression
- 4.4 Test Evaluation
  - 4.4.1 Test Data Criteria
  - 4.4.2 Test Data Reduction

SECTION 5. TEST (IDENTIFY) DESCRIPTION
- 5.1 Test Description
- 5.2 Test Control
  - 5.2.1 System Test Means of Control
  - 5.2.2 Test Data
    - 5.2.2.1 Input Data
    - 5.2.2.2 Input Commands
    - 5.2.2.3 Output Data
    - 5.2.2.4 Output Notification
- 5.3 Test Procedures
  - 5.3.1 Test Setup
  - 5.3.2 Test Initialization
  - 5.3.3 Test Steps
  - 5.3.4 Test Termination

Global Low Orbit Message Relay Satellite Passes
U.S.Customs Service Demonstration 10-02-86



Attachment 4

GLOMR

TEST PLAN

for the

U.S. Army Demonstration

18 September 1986

CONTRACT N00014-86-C-0330

Prepared by:
ARDAK Corporation
1493 Chain Bride Road, Suite 302
McLean, Virginia 22101

Prepared for:
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217-5000

SECTION 1. GENERAL

1.1 Purpose of this Test Plan. This test plan for Global Low Orbit Message Relay (GLOMR) demonstrations is written to fulfill the following objectives:

a. To coordinate an orderly schedule of events, equipment and organizational requirements, the methodology of testing, and a list of materials needed to support tests/briefings/demonstrations.

b. To provide guidance for the management and technical effort necessary throughout the test period.

c. To provide a written record of the actual test inputs, the instructions to permit execution of the test, and the expected outputs.

d. To communicate to the users the nature and extent of the tests deemed necessary to provide a basis for evaluation of the GLOMR system.

e. To familarize the readers with the components of the system - the satellite, the Master Ground Station (MGS), the Portable Earth Terminal (PET), the beacons, and NAVSPASUR ephemeris updates.

1.2 Project References.

a. DOD, Standard 7935 - Automated Data Systems Documentation Standards

b. DSI, GLOMR MGS User's Guide, Oct 85

c. DSI, Ground User's Terminal (GUT, PAT, or PET) User's Guide, Oct 85

d. PRC, GEODE User's Manual, Jan 86

e. ARDAK, Beacon Operations Manual, Aug 86

1.3 Terms and Abbreviations.

ARDAK	The GLOMR system integration contractor
DARPA	Defense Advanced Research Projects Agency
DSI	Defense Systems Incorporated - the GLOMR hardware contractor
LCD	Liquid Crystal Display
GEODE	Graphic Earth Orbit Display Environment
GLOMR	Global Low Orbit Message Relay
GMT	Greenwich Mean Time - also called Zulu time
MGS	Master Ground Station - located at a DSI facility in McLean, VA
MPS	Mission Planning System
NAVSPASUR	Navy Space Surveillance Command, Dalghren, VA
ONR	Office of Naval Research
PAT	Portable Access Terminal, also called PET
PET	Portable Earth Terminal - a briefcase size message terminal
PRC	Planning Research Corporation - a software subcontractor
RAM	Random Access Memory
TRS	Tandy Radio Shack Corporation

SECTION 2. DEVELOPMENT TEST ACTIVITY

2.1 Statement of Pretest Activity. The following test activities have been performed prior to this test.

a. GLOMR hardware integration test. The GLOMR satellite was bench tested prior to launch.

b. MGS software integration test. The MGS was tested in the lab.

c. MGS-GLOMR-MGS message test. Test messages were uplinked from the MGS and received back.

d. MGS-GLOMR uplink message. The MGS uplinked a message for this demonstration on orbit number 5103 at 01:00 GMT.

e. Beacon geolocation test. Normally, a beacon will be used to uplilnk signals for geolocation. This data is then relayed by GLOMR to the MGS and carried to PRC for analysis. For this demonstration, however, clock problems in the satellite have eliminated beacon geolocation data from being part of this demonstration.

2.2 Pretest Activity Results. The geolocation tests have experienced difficulties in downlinking data due to satellite and MGS operational problems and procedural errors. A known limitation in the message relay tests and demonstrations is the random loss of messages, primarily due to operational defects in the satellite.

SECTION 3. TEST PLAN

3.1 System Description. The GLOMR system concept is illustrated in Figure 3.1-1. The system consists of:

- o One inexpensive satellite, GLOMR, in low earth orbit since October 1985
- o One fixed Master Ground Station (MGS), located at DSI
- o One Portable Earth Terminal (PET), suitcase-sized
- o Two Beacons (7cm x 23cm x 23cm) operated stationary or mobile, and
- o Tracking and ephemeris update services provided by NAVSPASUR

3.1.1 The GLOMR Satellite. Figure 3.1-2 shows GLOMR and its dimensions. Its roughly spherical shape is made up of flat squares and triangles. The outside flat square surfaces are covered with solar cells. The antenna is omnidirectional; the radio operates at 287.4MHz transmit and receive. The satellite was launched from Shuttle flight 61A on 31 October 1985 with an inclinitation of 57.9 degrees. With the low orbit, useful passes last 5 to 10 minutes. The orbit period is roughly 90 minutes. Potential passes come in groups of three, followed by a 6-hour gap.

3.1.2 Master Ground Station (MGS). The MGS is located at the Defense Systems Incorporated offices in McLean, Virginia. It consists of a transmitter (10w output) and receiver identical to that inside the satellite, an antenna, and a DEC PDP-11 Minicomputer. The software performs the following functions:

- o Compute pass time schedule from NAVSPASUR ephemeris
- o Create tasking for the satellite
  - e.g., schedule on/off times
- o Communicate with the satellite
  - build and send messages
  - receive and decode messages, telemetry, and geolocation data

3.1.3 Portable Earth Terminal (PET). The PET is a suitcase sized terminal for sending and receiving GLOMR messages. The PET consists of a lap top microcomputer, the TRS-80-100, a helix antenna, and a transmitter and receiver identical to that in the MGS and the satellite. The computer and radio are housed in a suitcase sized carrying case. The microcomputer software allows the operator to create and send messages, and to receive and display incomming messages, but no geolocation data.

3.1.4 The Beacons. These are small transmitters designed and procured by ARDAK and used to test and demonstrate a capability to geolocate the transmitters (by an inverse doppler method). The beacons are hand held battery operated transmitters, with 2 watts of output power, which send simple signals to the satellite. The doppler shift in these signals is computed and relayed to the MGS where the location of the beacons can be computed by PRC software.

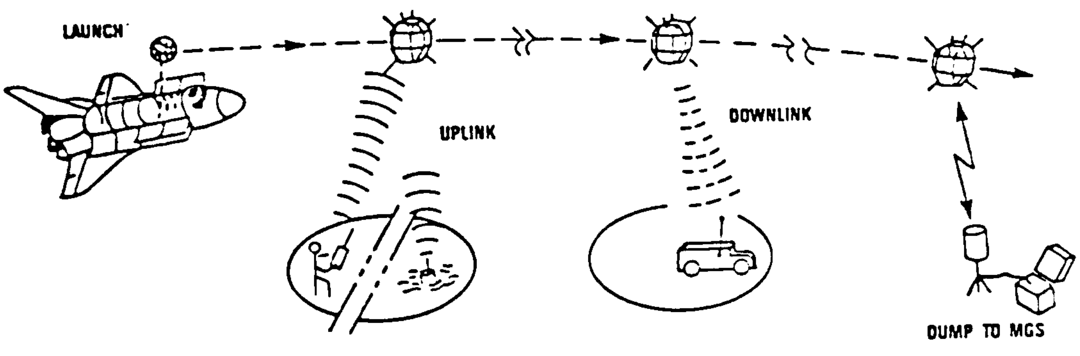


Figure 3.1-1. GLOMR System Concept

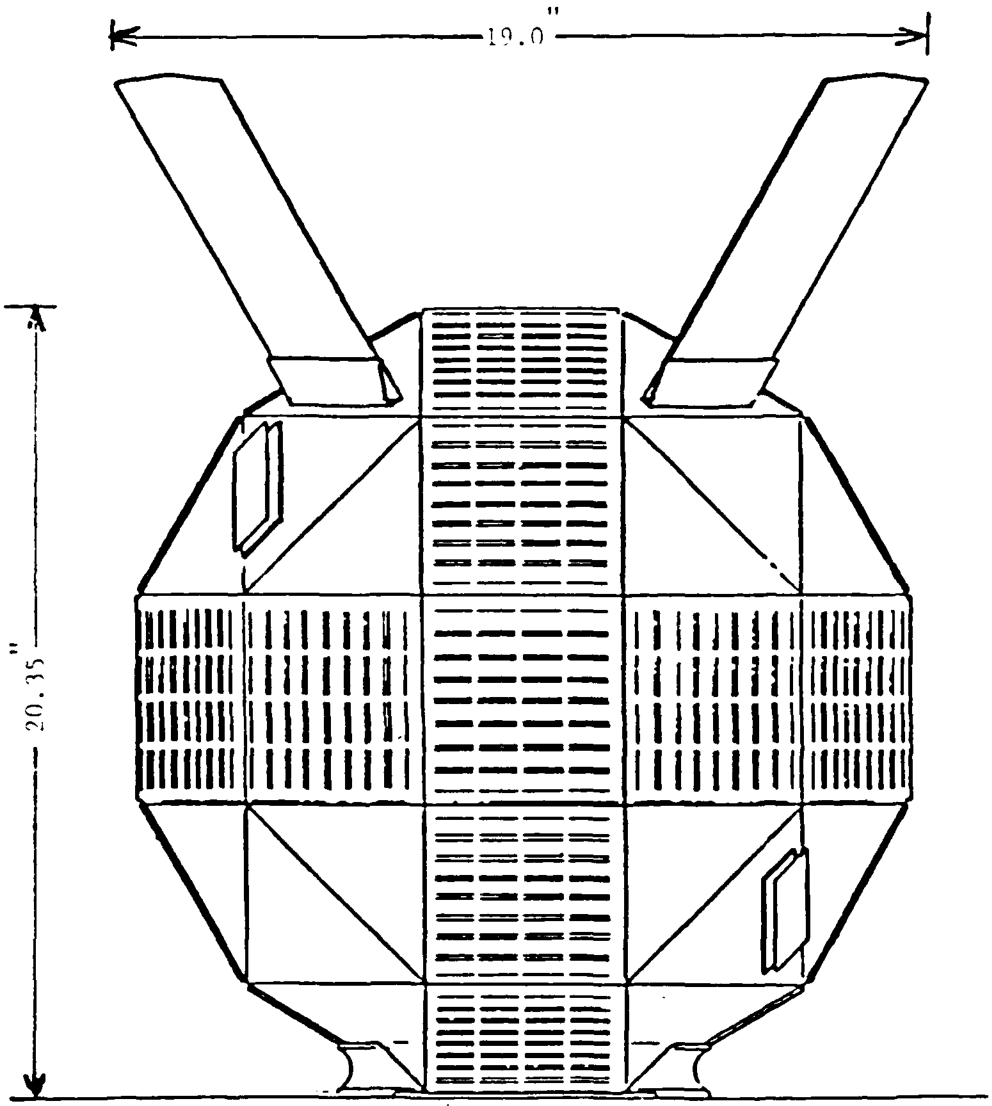


Figure 3.1-2. GLOMR Satellite

3.1.5 Tracking and Ephemeris. The Navy Space Surveillence Command (NAVSPASUR), Dalghren, Virginia, provides ephemeris updates to DSI via Telex. The updates are used to project pass schedules. The ephemeris data consists of: epoch, inclinination, eccentricity, mean motion, decay and other information. The time of the passes is needed to know when to turn on receivers and when to transmitt messages.

3.2 Testing Schedule. The GLOMR message relay tests are being conducted from June to October 1986. Geolocation tests commenced in August and are also continuing. The integration of message relay and geolocation tests and demonstrations are scheduled from Septmember until the end of operational life of the satellite.

3.3 Test 1 - Message Relay Demonstration. Todays demonstration will be perfomed at DSI in McLean, Virgina, by DSI, the GLOMR hardware contractor and ARDAK, the systems integration contractor.

3.3.1 Test 1 - Milestones.

09 Sep 86	Dry-run at DSI
10 Sep 86	Demonstration at DSI

3.3.2 Test 1 - Equipment Requirements.

a. The MGS at DSI will be used to uplink test messages.

b. The MGS at DSI will also be used to downling the test messages.

c. The PET, the bench test setup, and a beacon will be on static display

3.3.3 Software. All software being tested is part of the operational system. No special test software is needed. Geolocation data will be passed on to PRC where a new software program will be utilized to analyze the data for correct latitude/longitude/bias.

3.3.4 Personnel. During the pre-pass briefing, personnel will be located as follows.

a. MGS — MGS engineer - Mr. D. Powell

b. Conference Room — (For the pass, all of these people will move to the MGS)

LtCol. B. Bell, DARPA
LtCol. J. Crockett, USA
MajGen. R. Donahue, USA
Mr. N. Helm, ARDAK
Gen.(Ret) S. Meyer
Mr. J. O'Neil, DSI
Dr. G. Sebestyen, DSI
Mr. J. Slack, ARDAK
LtCol. N. Styer, USA
BrigGen. B. Thomas, USA

A beacon transmitter will be in the conference room on static display.

3.3.5 User Orientation Plan. Since GLOMR is an experimental proof of concept system, the purpose of this demonstration is simply to orient potential program users to the technical and operational capabilities of the GLOMR satellite system.

3.3.6 Test Materials. Prior to the demonstration, test messages will be generated and uplinked by the MGS. For the demonstration, vugraphs and a test plan have been developed. The technician will bring the following:

- o Compass
- o Accurate watch (GMT)
- o Pass opportunity schedule

3.3.6.1 Test Plan Document. ARDAK has prepared this test plan which documents the DoD standard test procedures, including the technical and operational parameters of the test, the pretest activities, test planning, activities and proposed results.

3.3.6.2 Deliverable Materials. Copies of the briefing and this test plan will be handed out. Since an operational capability is not being delivered, no technical user documentation will be delivered.

3.3.6.3 Site Supplied Materials. DSI will demonstrate and provide use of:

a. MGS for dry-run and demonstration.

b. Conference room with VCR/TV, Vugraph projector and screen.

c. Escorts as required by DSI procedures - for visiting personnel

d. Bench test setup with spare GLOMR satellite

e. The PET on static display

f. A beacon on static display.

3.3.7 Security and Privacy. The use of GLOMR is presently UNCLASSIFIED. The GLOMR system is not intended for the processing of data protected under the Privacy Act.

SECTION 4. TEST SPECIFICATION AND EVALUATION

4.1 Test Specification.

4.1.1. Requirements. This test will demonstrate satisfaction of the requirement to send messages via the GLOMR satellite, which includes the ability to uplink a message, store the message in GLOMR and forward the message to another ground station. No beacon geolocation data will be required as part of this demonstration.

4.1.2 System Functions. The following functions will be exercised in support of this demonstration.

a. Satellite Tracking. NAVSPASUR provides updated ephemeris data twice weekly.

b. Mission Planning.

(1) Opportunity Schedule. The times when GLOMR passes over the MGS/beacon are computed from the NAVSPASUR ephemerides. The demonstration and dry-runs are scheduled accordingly.

(2) Pass Plot. The PRC software, GEODE, is used to generate a computer plot showing the map of the U.S. overlaid with the selected uplink and downlink satellite passes. A copy of the plot is attached to this test plan.

c. Message Generation. Test messages are created on the MGS.

d. Message Uplink. The test messages are transmitted from the MGS to the satellite.

e. Message Store. The test messages are stored inside GLOMR until contact is made with the destination user.

f. Message Downlink. As the satellite passes the MGS, a scheduled command starts the GLOMR transmitter polling for the scheduled contact. The MGS responds with a "handshake" signal to this contact, and the messages addressed to the MGS are downlinked.

4.2 Data Recording. Copies of all briefing materials will be made for inclusion in the test analysis report. ARDAK personnel will request user feedback on the demonstration and on the potential applications of GLOMR. These feedback comments will be incorporated in the test analysis report, and collected for the Final Technical Report, which will summarize recommendations for future system enhancements and problem fixes.

4.3 Test Evaluation.

4.3.1 Test Data Criteria. The demonstration will be considered successful if the test message which was uplinked is received and displayed without error. Other technical and operational parameters will be evaluated to insure proper maintenance standards, along with proper logging and recording; these data will be kept for retrieval, the final report, and archival purposes.

4.3.2 Test Data Reduction. System test output will be displayed on the MGS screen, inspected visually, and printed out.

SECTION 5. TEST DESCRIPTION

5.1 Test Description. The purpose of this test is to demonstrate the GLOMR message capability. A test message will be uplinked from the MGS, stored in the satellite, and downlinked to the MGS. The MGS is located in McLean, Virginia. Prior to the pass, a short briefing will be given in the conference room. As the satellite passes, the MGS will communicate with GLOMR and store the test message in a buffer which will be displayed.

5.2 Test Control. The test will be initiated by manual means. The pass opportunity schedule gives the rise time of the pass; using a wristwatch, the MGS operator will set the current GMT time and schedule the communications sequence. The MGS will then automatically wait to be contacted by the GLOMR satellite. Once contacted, the MGS and GLOMR automatically exchange handshaking signals, the GLOMR telemetry packet and any messages are then downlinked.

5.3 Test Data. Test messages will be created and typed into the MGS - see the MGS User's Manual, reference 1.2.b. The test message is:

GLOMR WELCOMES GENS DONAHUE AND THOMAS

5.4 Input Commands. The MGS operator enters the appropriate rise time (GMT).

5.5 Output Data. Once received, the contents of the message are displayed on the screen and printed out. The display should resemble the following:

GLOMR WELCOMES GENS DONAHUE AND THOMAS

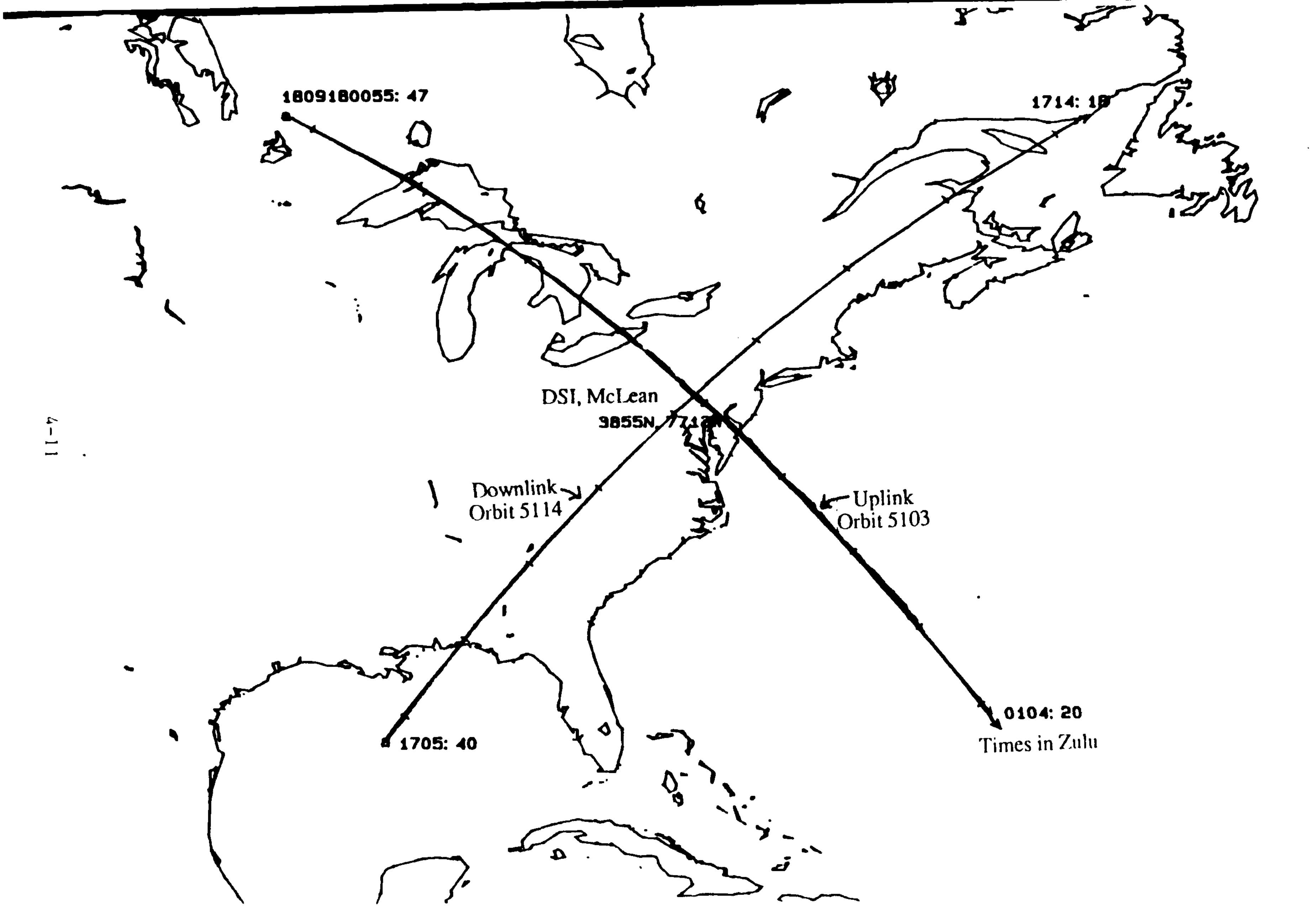
The received message will also be stored in a file.

5.6 Test Termination. The test will be discussed with the audience to answer any questions and to solicit user feedback on GLOMR and the demonstration itself.

ATTACHMENT 1

ARDAK

Global Low Orbit Message Relay Satellite Passes
U.S. Army Demonstration 09-18-86



Attachment 5

GLOMR

TEST PLAN

for the

U.S. Customs Service Demonstration

San Diego, California

02 October 1986

CONTRACT N00014-86-C-0330

Prepared by:
ARDAK Corporation
1493 Chain Bridge Road, Suite 302
McLean, Virginia 22101

Prepared for:
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217-5000

SECTION 1. GENERAL

1.1 Purpose of this Test Plan. This test plan for Global Low Orbit Message Relay (GLOMR) demonstrations is written to fulfill the following objectives:

a. To coordinate an orderly schedule of events, equipment and organizational requirements, the methodology of testing, and a list of materials needed to support tests/briefings/demonstrations.

b. To provide guidance for the management and technical effort necessary throughout the test period.

c. To provide a written record of the actual test inputs, the instructions to permit execution of the test, and the expected outputs.

d. To communicate to the users the nature and extent of the tests deemed necessary to provide a basis for evaluation of the GLOMR system.

e. To familarize the readers with the components of the system - the satellite, the Master Ground Station (MGS), the Portable Earth Terminal (PET), the beacons, and NAVSPASUR ephemeris updates.

1.2 Project References.

a. DOD, Standard 7935 - Automated Data Systems Documentation Standards

b. DSI, GLOMR MGS User's Guide, Oct 85

c. DSI, Ground User's Terminal (GUT, PAT, or PET) User's Guide, Oct 85

d. PRC, GEODE User's Manual, Jan 86

e. ARDAK, Beacon Operations Manual, Aug 86

1.3 Terms and Abbreviations.

ARDAK	The GLOMR system integration contractor
DARPA	Defense Advanced Research Projects Agency
DSI	Defense Systems Incorporated - the GLOMR hardware contractor
LCD	Liquid Crystal Display
GEODE	Graphic Earth Orbit Display Environment
GLOMR	Global Low Orbit Message Relay
GMT	Greenwich Mean Time - also called Zulu time
MGS	Master Ground Station - located at a DSI facility in McLean, VA
MPS	Mission Planning System
NAVSPASUR	Navy Space Surveillance Command, Dalghren, VA
ONR	Office of Naval Research
PAT	Portable Access Terminal, also called PET
PET	Portable Earth Terminal - a briefcase size message terminal
PRC	Planning Research Corporation - a software subcontractor
RAM	Random Access Memory
TRS	Tandy Radio Shack Corporation
USCS	United States Customs Service

SECTION 2. DEVELOPMENT TEST ACTIVITY

2.1 Statement of Pretest Activity. The following test activities have been performed prior to this test.

a. GLOMR hardware integration test. The GLOMR satellite was bench tested prior to launch.

b. MGS software integration test. The MGS was tested in the lab.

c. The beacons were bench tested, and then as part of their acceptance tests, were successfully tested with the satellite.

d. Pass opportunity schedule. Detailed schedules of available passes are printed out for use in planning the demonstrations and scheduling the satellite contacts.

e. Schedule uplink. The task list for the satellite to execute is uplinked by the MGS. In this test and demonstration the satellite is scheduled the early afternoon of October, 02 to poll the beacon in San Diego, CA three times during orbit 5341.

f. Clock set. If necessary, the satellite clock is updated to the current time.

g. Beacon geolocation test. A beacon is used to uplink signals for geolocation. This data is then relayed by GLOMR to the MGS and carried to PRC for analysis.

2.2 Pretest Activity Results. The geolocation tests have experienced difficulties in downlinking data due to satellite and MGS operational problems and procedural errors. A known limitation in the message relay tests and demonstrations is the random loss of messages, primarily due to operational defects in the satellite.

SECTION 3. TEST PLAN

3.1 System Description. The GLOMR system concept is illustrated in Figure 3.1-1. The system consists of:

- o One inexpensive satellite, GLOMR, in low earth orbit since October 1985
- o One fixed Master Ground Station (MGS), located at DSI
- o One Portable Earth Terminal (PET), suitcase-sized
- o Two Beacons (7cm x 23cm x 23cm) operated stationary or mobile, and
- o Tracking and ephemeris update services provided by NAVSPASUR

3.1.1 The GLOMR Satellite. Figure 3.1-2 shows GLOMR and its dimensions. Its roughly spherical shape is made up of flat squares and triangles. The outside flat square surfaces are covered with solar cells. The antenna is omnidirectional; the radio operates at 287.4MHz transmit and receive. The satellite was launched from Shuttle flight 61A on 31 October 1985 with an inclinitation of 56.9 degrees. With the low orbit, useful passes last 5 to 10 minutes. The orbit period is roughly 90 minutes. Potential passes come in groups of three, followed by a 6-hour gap.

3.1.2 Master Ground Station (MGS). The MGS is located at the Defense Systems Incorporated offices in McLean, Virginia. It consists of a transmitter (10w output) and receiver identical to that inside the satellite, an antenna, and a DEC PDP-11 Minicomputer. The software performs the following functions:

- o Compute pass time schedule from NAVSPASUR ephemeris
- o Create tasking for the satellite
  - e.g., schedule on/off times
- o Communicate with the satellite
  - build and send messages
  - receive and decode messages, telemetry, and geolocation data

3.1.3 Portable Earth Terminal (PET). The PET is a suitcase sized terminal for sending and receiving GLOMR messages. The PET consists of a lap top microcomputer, the TRS-80-100, a helix antenna, and a transmitter and receiver identical to that in the MGS and the satellite. The computer and radio are housed in a suitcase sized carrying case. The microcomputer software allows the operator to create and send messages, and to receive and display incomming messages, but no geolocation data. A hand held PET is currently being developed by Defense Systems, Inc. of McLean, VA. This unit has a built in keyboard and can primarily duplicate the suitcase terminal.

3.1.4 The Beacons. These are small transmitters designed and procured by ARDAK and used to test and demonstrate a capability to geolocate the transmitters (by an inverse doppler method). The beacons are hand held battery operated transmitters, with 2 watts of output power, which send simple signals to the satellite. The doppler shift in these signals is computed and relayed to the MGS where the location of the beacons can be computed by PRC software.

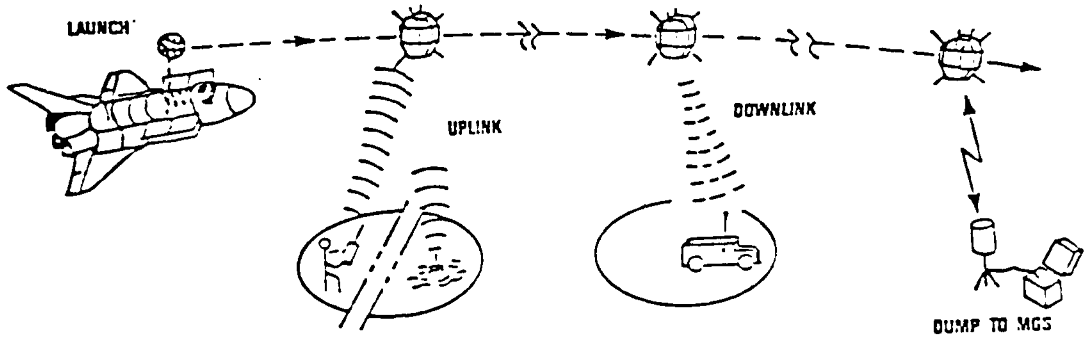


Figure 3.1-1. GLOMR System Concept

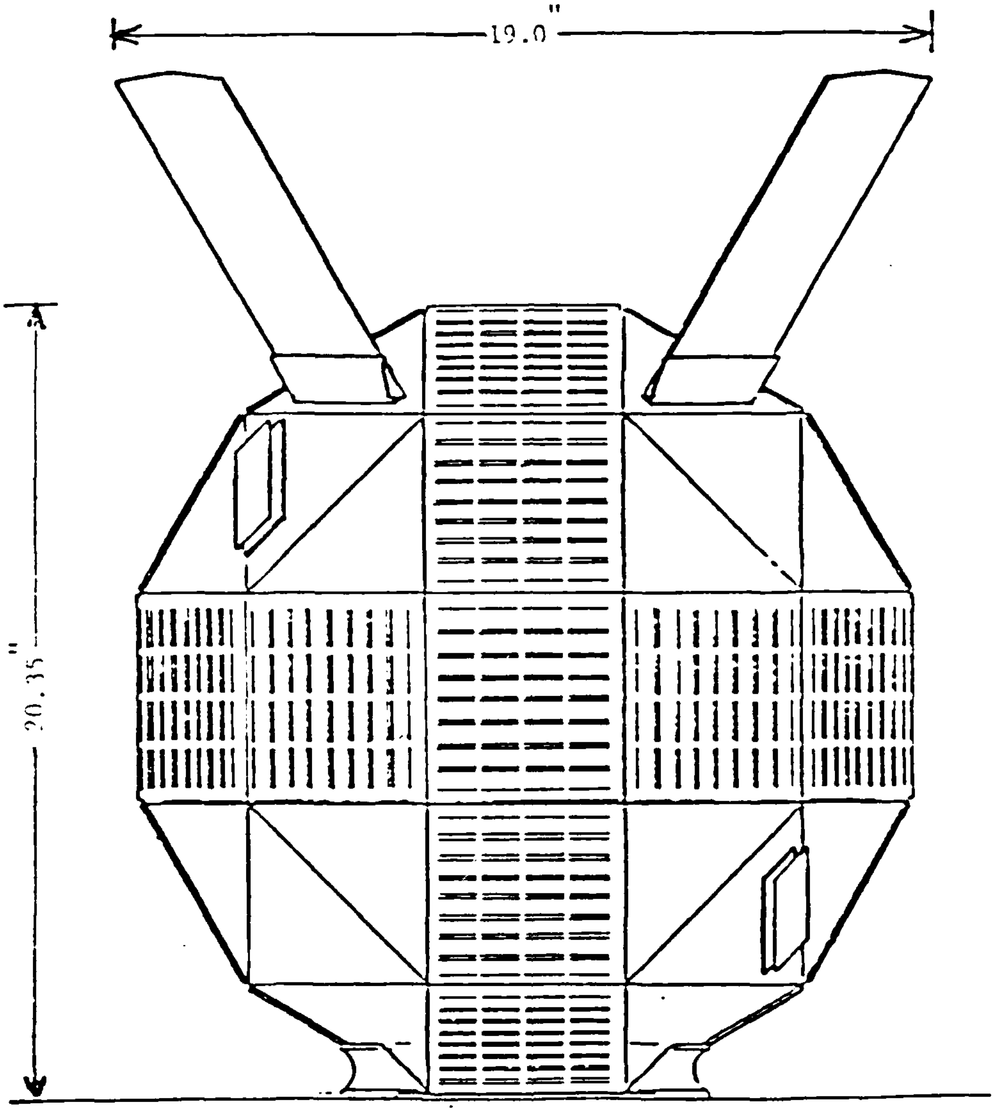


Figure 3.1-2. GLOMR Satellite

3.1.5 Tracking and Ephemeris. The Navy Space Surveillence Command (NAVSPASUR), Dalghren, Virginia, provides ephemeris updates to DSI via Telex. The updates are used to project pass schedules. The ephemeris data consists of: epoch, inclinination, eccentricity, mean motion, decay and other information. The time of the passes is needed to know when to turn on receivers and when to transmitt messages.

3.2 Testing Schedule. The GLOMR message relay tests are being conducted from June to October 1986. Geolocation tests commenced in August and are also continuing. The integration of message relay and geolocation tests and demonstrations are scheduled from September until the end of operational life of the satellite.

3.3 Test 1 - Geolocation Demonstration. The demonstration will be perfomed at the U.S. Customs Service (USCS), San Diego, California, by ARDAK Corporation, the systems integration contractor.

3.3.1 Test 1 - Milestones.

01 Oct 86	Demonstration at USCS El Paso, TX
02 Oct 86	Demonstration at USCS San Diego, CA

3.3.2 Test 1 - Equipment Requirements.

a. The MGS at DSI will be used to downlink geolocation data.

b. The Beacon at the USCS will be used to uplink geolocation data.

3.3.3 Software. All software being tested is part of the operational system. No special test software is needed. Geolocation data will be passed on to PRC where a new software program will be utilized to analyze the data for correct latitude/longitude/bias.

3.3.4 Personnel. During the pre-pass briefing, personnel will be located at the USCS. The briefer will be Mr. Neil Helm, ARDAK Corporation, Director of Communications Systems. For the pass, everyone will move to a clear view area.

3.3.5 User Orientation Plan. Since GLOMR is an experimental proof of concept system, the purpose of this demonstration is simply to orient potential program users to the technical and operational capabilities of the GLOMR satellite system.

3.3.6 Test Materials. For the demonstration, a videotape, vugraphs and a test plan have been developed. The demonstrator will have the following:

- o Compass
- o Accurate watch (GMT)
- o Pass opportunity schedule
- o Handouts

3.3.6.1 Test Plan Document. ARDAK has prepared this test plan which documents the DoD standard test procedures, including the technical and operational parameters of the test, the pretest activities, test planning, activities and proposed results.

3.3.6.2 Deliverable Materials. Copies of the briefing and this test plan will be handed out. Since an operational capability is not being delivered, no technical user documentation will be delivered.

3.3.6.3 Site Supplied Materials. The USCS will provide use of:

a. Conference room
b. VHS videotape player and TV monitor
c. Vugraph projector

3.3.7 Security and Privacy. The use of GLOMR is presently UNCLASSIFIED. The GLOMR system is not intended for the processing of data protected under the Privacy Act.

SECTION 4. TEST SPECIFICATION AND EVALUATION

4.1 Test Specification.

4.1.1. Requirements. This test will demonstrate satisfaction of the requirement to send geolocation data via the GLOMR satellite, which includes the ability to uplink a signal, store the data in GLOMR and forward the data to another ground station.

4.1.2 System Functions. The following functions will be exercised in support of this demonstration.

a. Satellite Tracking. NAVSPASUR provides updated ephemeris data twice weekly.

b. Mission Planning.

(1) Opportunity Schedule. The times when GLOMR passes over the MGS beacon are computed from the NAVSPASUR ephemerides. The demonstration and dry-runs are scheduled accordingly.

(2) Pass Plot. The PRC software, GEODE, is used to generate a computer plot showing the map of the U.S. overlaid with the selected uplink and downlink satellite passes. A copy of the plot is attached to this test plan.

c. Signal Generation. The beacon generates the geolocation signal.

d. Signal Storage. The signals are stored inside GLOMR until contact is made with the destination user.

f. Data Downlink. As the satellite passes the MGS, a scheduled command starts the GLOMR transmitter polling for the scheduled contact. The MGS responds with a "handshake" signal to this contact, and the data addressed to the MGS is downlinked.

4.2 Data Recording.

Copies of all briefing materials will be made for inclusion in the test analysis report. ARDAK personnel will request user feedback on the demonstration and on the potential applications of GLOMR. These feedback comments will be incorporated in the test analysis report, and collected for the Final Technical Report, which will summarize recommendations for future system enhancements and problem fixes.

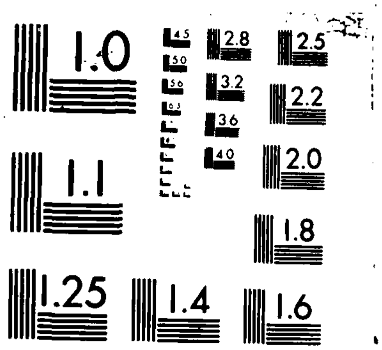
4.3 Test Evaluation.

4.3.1 Test Data Criteria. The demonstration will be considered successful if the test data which were uplinked are received and displayed without error. Other technical and operational parameters will be evaluated to insure proper maintenance standards, along with proper logging and recording; these data will be kept for retrieval, the final report, and archival purposes.

4.3.2 Test Data Reduction. Test output on the MGS will be copied to the printer

AD-A177 383 GLOBAL LOW ORBIT MESSAGE RELAY (GLOMR) SATELLITE APPLICATIONS DEVELOPMENT PRGRAM(U) ARDAK CORP MCLEAN VA J L SLACK ET AL. 30 SEP 86 ARDAK-8603-01 2/2

UNCLASSIFIED N00014-86-C-0330 F/G 17/2 NL



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

SECTION 5. TEST DESCRIPTION

5.1 Test Description. The purpose of this test is to demonstrate the GLOMR geolocation capability. A test signal will be uplinked from the Beacon, stored in the satellite, and downlinked to the MGS. The MGS is located in McLean, Virginia. Prior to the pass, a short briefing will be given in the conference room. As the satellite passes, the Beacon will communicate with GLOMR and store the test signal data in a buffer which will be relayed to the MGS.

5.2 Test Control. The test will be initiated by manual means. The pass opportunity schedule gives the rise time of the pass; using a wristwatch, the Beacon operator will power on the Beacon and the receiver. He will then wait to be contacted by the GLOMR satellite by listening to the receiver. Once contacted, the beacon transmitter will be keyed on. This sequence will be repeated three times during a pass.

5.3 Test Data. Test signals are built-in to the Beacon read only memory. The test scheduel is:

Event	Description	Orbit	Date	Time GMT
1	Uplink from Beacon	5320	10/01	1402
2	Downlink to MGS	5323	10/01	1855

Detailed pass schedules are at attachment 2.

5.4 Output Data. Once received by the MGS, the contents of the geolocation data message are displayed on the screen, printed out, and stored in a file. The data will resemble Figure 5.4-1.

5.5 Test Termination. The test will be discussed with the audience to answer any questions and to solicit user feedback on GLOMR and the demonstration itself.

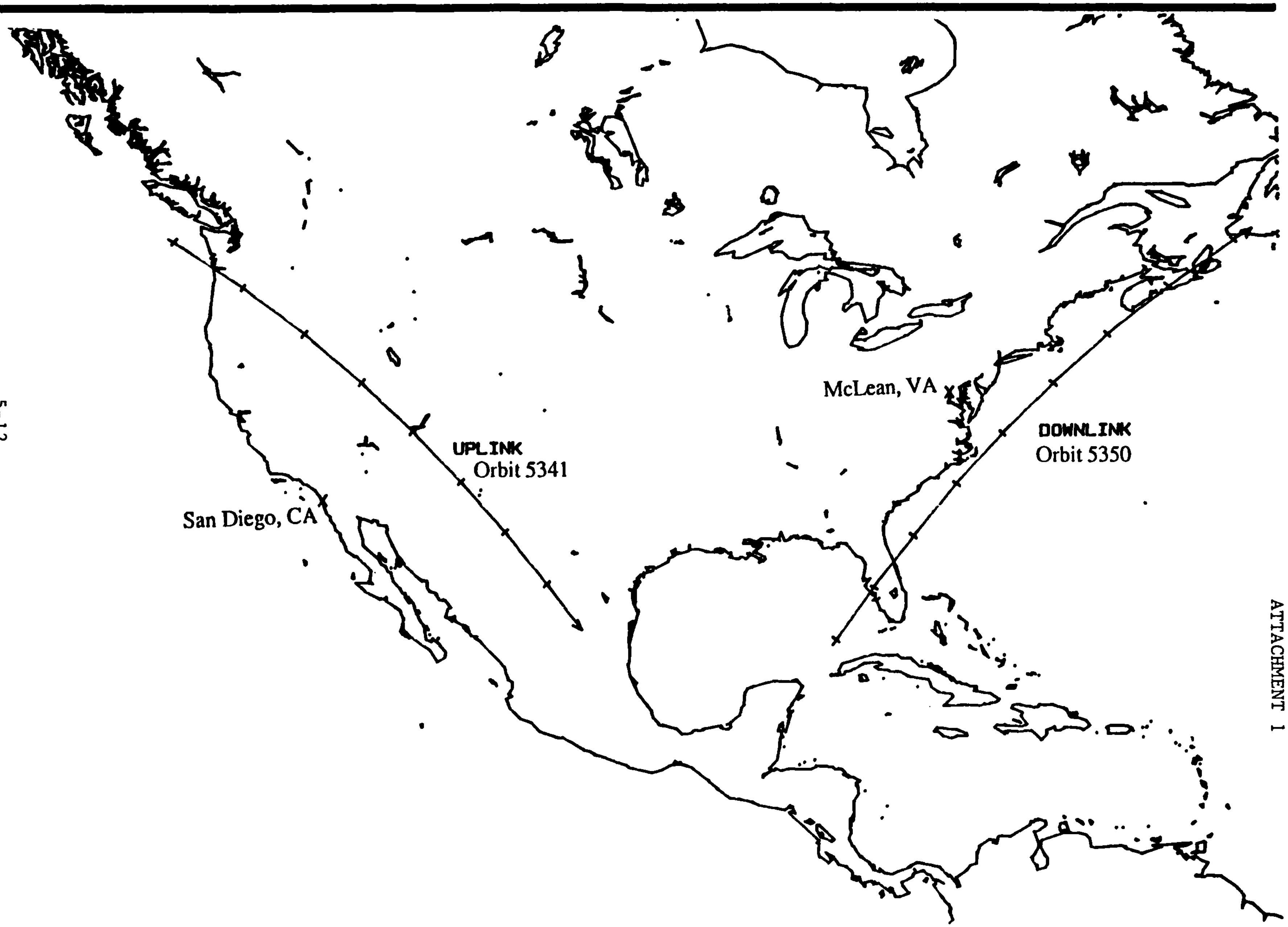
```
Record # 88

      Type ID          7
      ODAC             2
      DDAC             1
      Geolocation ID      2
      Geolocation Count 21
      Geolocation Time 88/08.13  14:53:44
```

$$\underbrace{1}_{\text{Flag}}\quad \underbrace{0\ \ 81\ 153\ \ 38}_{\text{Input Freq}}\quad \underbrace{0\ \ 50\ 188\ \ 63}_{\text{Local Oscillator Freq}}\quad \underbrace{14\ \ 53\ \ 10\ 241\ \ 24\ \ 93}_{\text{Time}}$$

Figure 5.4-1. Example geolocation data printout

ARDAK

Global Low Orbit Message Relay Satellite Passes
U.S.Customs Service Demonstration 10-02-86



ATTACHMENT 1

ATTACHMENT 2

U.S. Customs Service San Diego, California
Geolocation Contact Times

ORBIT Ver. 3.1 -- Visibility Analysis --

Date/Time (Z) YY/MM/DD	HH:MM:SS	Elev Deg	Azim Deg	Alt Nmi	Slant Nmi	Lat Deg	Lon Deg	Doppler Hz	
86/10/02	21:54:01	0.1	337.1	151.3	1025.5	47.728	-126.744	6317.8	
86/10/02	21:54:11	0.7	338.0	151.3	990.1	47.332	-125.995	6278.1	
86/10/02	21:54:21	1.3	339.0	151.2	954.9	46.930	-125.258	6233.1	
86/10/02	21:54:31	1.9	340.0	151.2	920.0	46.523	-124.533	6182.0	
86/10/02	21:54:41	2.6	341.2	151.1	885.4	46.112	-123.819	6123.9	
86/10/02	21:54:51	3.3	342.4	151.0	851.1	45.695	-123.116	6057.7	
86/10/02	21:55:01	4.0	343.7	151.0	817.2	45.273	-122.424	5952.3	
86/10/02	21:55:11	4.7	345.2	150.9	783.8	44.847	-121.743	5896.0	
86/10/02	21:55:21	5.5	346.7	150.8	750.9	44.416	-121.073	5797.3	1st Contac
86/10/02	21:55:31	6.3	348.5	150.8	718.6	43.981	-120.413	5683.9	
86/10/02	21:55:41	7.1	350.3	150.7	687.0	43.541	-119.763	5553.6	
86/10/02	21:55:51	8.0	352.4	150.6	656.2	43.098	-119.123	5403.4	
86/10/02	21:56:01	8.9	354.7	150.6	626.3	42.650	-118.493	5230.1	
86/10/02	21:56:11	9.8	357.2	150.5	597.4	42.198	-117.873	5029.7	
86/10/02	21:56:21	10.8	359.9	150.4	569.7	41.743	-117.262	4798.0	
86/10/02	21:56:31	11.7	3.0	150.3	543.5	41.284	-116.660	4530.3	
86/10/02	21:56:41	12.7	6.4	150.3	518.8	40.821	-116.067	4221.5	
86/10/02	21:56:51	13.7	10.1	150.2	496.0	40.355	-115.483	3866.7	
86/10/02	21:57:01	14.7	14.2	150.1	475.4	39.885	-114.907	3461.5	
86/10/02	21:57:11	15.6	18.7	150.0	457.2	39.412	-114.340	3002.9	
86/10/02	21:57:21	16.4	23.5	150.0	441.7	38.936	-113.781	2490.3	2nd Contac
86/10/02	21:57:31	17.1	28.8	149.9	429.2	38.457	-113.230	1926.2	
86/10/02	21:57:41	17.7	34.3	149.8	420.1	37.974	-112.686	1317.7	
86/10/02	21:57:51	18.0	40.0	149.7	414.4	37.489	-112.151	675.9	
86/10/02	21:58:01	18.1	45.9	149.7	412.4	37.001	-111.622	16.1	
86/10/02	21:58:11	18.0	51.9	149.6	414.2	36.510	-111.101	-644.3	
86/10/02	21:58:21	17.6	57.6	149.5	419.6	36.017	-110.587	-1287.8	
86/10/02	21:58:31	17.1	63.1	149.4	428.6	35.521	-110.090	-1899.0	
86/10/02	21:58:41	16.4	68.3	149.3	440.9	35.022	-109.579	-2466.3	
86/10/02	21:58:51	15.6	73.2	149.3	456.2	34.521	-109.085	-2982.6	
86/10/02	21:59:01	14.6	77.7	149.2	474.3	34.018	-108.598	-3445.0	
86/10/02	21:59:11	13.7	81.9	149.1	494.8	33.512	-108.117	-3853.9	
86/10/02	21:59:21	12.7	85.6	149.0	517.5	33.004	-107.641	-4212.1	3rd Contac
86/10/02	21:59:31	11.7	89.0	149.0	542.1	32.494	-107.172	-4524.0	
86/10/02	21:59:41	10.7	92.1	148.9	568.3	31.982	-106.708	-4794.6	
86/10/02	21:59:51	9.7	94.9	148.8	595.9	31.468	-106.250	-5028.8	
86/10/02	22:00:01	8.8	97.4	148.7	624.8	30.951	-105.797	-5231.4	
86/10/02	22:00:11	7.9	99.7	148.7	654.7	30.433	-105.350	-5406.7	
86/10/02	22:00:21	7.0	101.7	148.6	685.6	29.913	-104.907	-5558.7	
86/10/02	22:00:31	6.2	103.6	148.5	717.2	29.391	-104.470	-5690.6	
86/10/02	22:00:41	5.4	105.3	148.4	749.6	28.867	-104.037	-5805.4	
86/10/02	22:00:51	4.6	106.9	148.3	782.5	28.342	-103.610	-5905.4	
86/10/02	22:01:01	3.9	108.4	148.3	816.0	27.815	-103.186	-5992.9	
86/10/02	22:01:11	3.1	109.7	148.2	849.9	27.286	-102.768	-6069.4	
86/10/02	22:01:21	2.5	110.9	148.1	884.3	26.756	-102.353	-6136.6	
86/10/02	22:01:31	1.8	112.1	148.1	919.0	26.225	-101.943	-6195.7	
86/10/02	22:01:41	1.1	113.1	148.0	954.0	25.691	-101.537	-6247.7	
86/10/02	22:01:51	0.5	114.1	147.9	989.2	25.157	-101.134	-6293.6	

The Above Data is for ORBIT NO. 5341 : Total PASSTIME(Min)= 7.969

Attachment 6

Defense Systems Inc.

An Engineering Technologies, Inc. Company

GLOMR ANOMALY REPORT

VERSION 1.0

October 30, 1986

7903 Westpark Drive . McLean, Virginia 22102 . (703) 883-1000 . Telex 709272

S = Successful
PS = Partially Successful
F1 = Failure of Satellite
F2 = Failure of Operator
F3 = Failure of MGS
F4 = Unknown

GLOMR CONTACT STATISTICS

DATE	TIME(Z)	ELEV.	FUNCTION	RESULT
7/8	2231	78.8	PRL-PAT TEST	S-Telemetry and Message
7/9	0455	8.8	"	PS-Telemetry Only
7/9	0623	32.9	"	S-Telemetry and Message
7/9	1937	68.6	"	F2-Not Scheduled
7/9	2103	11.4	"	F2-Not Scheduled
7/9	2237	29.6	"	PS-Telemetry Only
7/10	0329	69.0	"	S-Uplink Schedule and Message
7/10	0631	80.6	"	S-Received Telemetry and Message (PRL)
7/10	1941	39.9	"	PS-Received Telemetry Only
7/10	2110	20.9	"	F4-Local Interference
7/10	2241	13.7	"	F2-Incorrect PAT Entries
7/11	0336	25.8	"	PS-Telemetry Only
7/11	0638	27.5	"	F4
7/11	1822	19.3	Uplink Schedule at DSI for Path Loss	S
7/14	1705	14.6	"	S
7/15	1702	34.1	"	S
7/17	1548	10.8	"	S
7/20	1717	19.1	"	S
7/22	1435	45.7	Path Loss Measurement	S
7/23	2237	37.9	Message Up	S
7/24	1450	25.6	Message Down	F4
7/24	2105	23.4	Path Loss Measurement	S
7/29	2002	88.9	"	F2-Missed Contact
7/30	1001	11.4	"	S
7/30	1210	52.0	"	S
8/7	1732	12.0	"	S
8/8	1602	57.2	Clock Reset	S
8/11	2041	14.1	Clock Reset	S
8/12	1447	31.5	ARDAK Beacon Quality Test	S-Richmond, VA Test
8/13	0652	18.9	"	"
8/14	1323	34.4	"	"

GLOMR CONTACT STATISTICS (CONT.)

DATE	TIME(Z)	ELEV.	FUNCTION	RESULT
8/19	1036	61.1	Clock Reset	S
8/20	0417	64.7	Schedule Up	S
8/20	1036	12.1	ARDAK Beacon Geolocate	F1-Clock Reset
8/21	0248	12.7	"	F1-Clock Reset
8/22	0251	26.2	Clock Reset	S
8/23	0255	68.0	ARDAK Beacon Geolocate	F3-Transceiver Rain Damaged
8/23	0429	3.9	"	"
8/23	0914	8.8	"	"
8/23	1046	74.8	"	"
8/25	0302	21.7	Geo Data Downlink	F3-Discover Rain Damage, Repair
8/26	0133	35.7	Schedule Up	S
8/26	0305	12.4	ARDAK Beacon Geolocate	F2-Excessive Schedule Uplink; GLOMR Reset
8/26	0923	58.8	"	"
8/27	0134	85.1	"	"
8/27	0309	7.4	"	"
8/28	0009	9.7	Schedule Up	F4-Interference(?)
8/28	0138	34.0	Clock Reset	S
8/28	0932	22.1	"	S
8/29	0933	10.5	Listen for Beep/ Receive	S
8/30	0011	43.6	Schedule Up	S
8/30	0145	10.5	ARDAK Beacon Geolocate	PS-Telemetry Only, No Geolocate Data
8/30	0802	80.1	"	"
8/31	0014	62.4	"	"
8/31	0636	12.4	Geo Data Downlink and Schedule Uplink	PS-Telemetry Only
8/31	2244	12.3	ARDAK Beacon Geolocate	"
9/03	2118	6.2	"	"
9/03	2250	50.9	"	"
9/04	2120	14.0	Geo Data Downlink and Schedule Uplink	"

GLOMR CONTACT STATISTICS (CONT.)

DATE	TIME(Z)	ELEV.	FUNCTION	RESULT
9/04	2253	22.3	ARDAK Beacon Geolocate	PS-Telemetry Only
9/05	0511	23.4	Clock Reset	S
9/05	0644	15.4	ARDAK Beacon Geolocate	PS-Telemetry Only
9/05	2302	12.9	"	PS
9/06	0513	48.4	Schedule Uplink	S
9/06	2124	77.1	ARDAK Beacon Geolocate	F4
9/07	2126	41.2	"	F2
9/08	0345	15.2	"	F1-Incorrect Clock
9/08	0525	24.2	"	"
9/09	0347	26.7	Clock Reset	S
9/09	0520	13.2	Message Uplink	S
9/09	2131	12.3	Message Down	S-ONR Demo
9/10	0358	65.7	Schedule Uplink	S
9/11	0350	56.4	ARDAK Beacon Geolocate	PS-Telemetry Only
9/12	0219	16.3	"	S-Geolocate Record

GLOMR LIMITATIONS

LIMITATION	ACTION
• **HARDWARE**	
– Phase Response of Receiver Intermediate Filter	– Filter Changed in Ground Station. Operations Nominal.
– Satellite on-Board Memory	– None; Next GLOMR Build
– Clock Drift Rate Too High ($\approx$ 30 seconds/3 weeks)	– None; Next GLOMR Build
– PAT Computer TRS80 Cumbersome	– None; Minor Operational Constraint
• **SOFTWARE**	
– Labor Intensive MGS Operations	– In Process: Advance Scheduling and Enhanced Data Capture
– Geolocation	– In Process: Await PRC Input

SUGGESTED SYSTEM REFINEMENTS

SATELLITE

ANOMALY	REFINEMENTS
Satellite has limited memory, therefore can't send up more than 256 characters per pass	Expand memory in satellite
Events cannot occur closer than 2 minutes apart	Modify timing sequences in satellite
Satellite presently tries once to deliver message then erases message	Modify so satellite keeps message until it makes contact with addressee
	Need clear, concise reporting of telemetry data
Clock drifts up to 30 sec. per month	Need more stable/accurate clock

MASTER GROUND STATION

ANOMALY	REFINEMENT
Problems with transmitter/receiver	Improve packaging to be more weatherproof
Loose messages that are not perfect	Capture, store, time tag, and report all dowlink data
Ground station is personnel intensive	Automate ground station to provide advanced scheduling and operation of satellite contacts
	Automatic output of contact records
	Automatic generation of log
Excessive interference at this location	Provide remote site for testing
	Allow variable contacts for communications
Geolocation	Geolocation software required to support beacon testing and subsequent operational requirements
Improved display/printing capabilities	Need to print messages as well as scheduling waiting to be uplinked

PORTABLE ACCESS TERMINAL

ANOMALY	REFINEMENTS
File confusion	Combine all uplink messages into one file, as in MGS, where some are marked active and some deleted. Be able to display active messages.
Timing problems	Display present time on screen
	When a contact is initiated, compare schedule contact time to present time and signal operator if contact time has passed or if time is too far in the future.
	Allow for manual override of schedule to contact satellite
Downlink file control	Time tag and save all downlinked messages
	Provide housekeeping functions to keep memory from being cluttered with old data

END

4 — — 87

DTIC